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THE SCIENCE TEACHER

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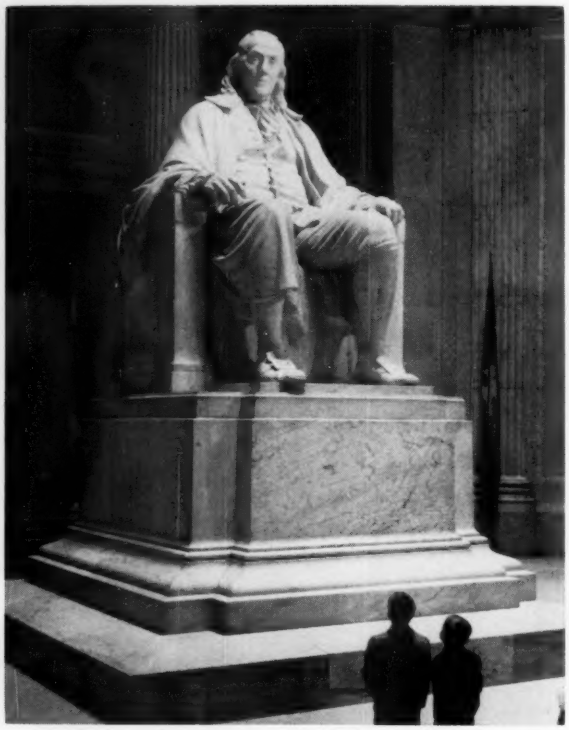

THIS MONTH'S COVER . . . is in honor of Benjamin Franklin—born January 17th, 1706. Science teachers and their students will want to take part, in their own way, in the International Celebration of the 250th Anniversary of the birth of this great leader which will continue throughout the year of 1956. For information and material on the celebration, write to The 250th Anniversary Committee for the Franklin Institute, Benjamin Franklin Parkway at Twentieth, Philadelphia 3, Pennsylvania.

We are indebted to the Franklin Institute for the cover picture and to the Anniversary Committee for permission to adapt the following excerpts from their Program booklet.

"MR. FRANKLIN, SIR"—

In these words, the famous actor, Charles Laughton, recently stood before the Memorial to Benjamin Franklin and so addressed the heroic statue as though it were alive. Science teachers may well use the same words, saying, "Mr. Franklin, Sir, we honor you. You were America's first great scientist and engineer. You were one of that group of thinkers, in all countries, who helped lay the foundations for the spectacular technological developments of today. Your theory of the 'positive-negative electric fluid' is still the basis for the vast and complex electric industry—now mankind's most useful servant.

"The world will remember you for your courageous leadership in teaching that the enormous forces of nature are not to be viewed, as lightning was—in fearful superstition of the unknown. You were incredibly curious about the Universe and believed that man should study it, not fear it. By example, you studied storms, whirlwinds, and the mighty Gulf Stream. You fought marsh gas, fires, and communicable diseases. You lampooned the superstitions of thousands of years and advocated open and continuous research in nearly all fields.

"Your wise humanity lives today in the splendid schools and colleges of our land where every boy and girl, as you proposed, may freely elect to learn those things that will be most useful in later life. Although you had only two years of formal schooling, you were one of the great educational leaders of your day. You advocated education for all, regardless of race, color, creed, or social position; you created the elective system of preparing for future work in life. Your 'Proposals' brought the teaching of technical and scientific subjects into our schools and colleges for the first time.

"For all these things and many more, Mr. Franklin, Sir, we honor you. In 1956 and in years to follow, we will exert our efforts to help relieve the world's critical shortage of young scientists, technicians, engineers, and science teachers. Coupled with this effort will be an equally vigorous effort to help all youth achieve better knowledge and understanding of science and scientists, to the end that all may benefit from the scientific endeavor and wisely help guide and support it."

THE SCIENCE TEACHER

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MEMBERSHIP

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Coming . . .

in the March issue of *The Science Teacher*

- Convention Highlights
- Metallurgical Engineering as a Career
- Incorporating Cancer Information in the Secondary School Program
- Trends in Junior High General Science

Editor's Column

"Say, you science teachers are really sitting pretty; everyone seems to want more science in the schools these days!" That's what a fellow-delegate at the recent White House Conference on Education said to me. He is neither a scientist nor educator; he's a layman working for a business organization. Even so, he sensed one of the main currents of thought underlying the Conference, and for that matter, much of today's thinking about educational problems.

My friend was right, too. I was participating in the White House Conference as your official representative for our Association. During the sessions I had been most gratified to hear repeated references to the increasing need for technically trained personnel, for more qualified science teachers, and for more youngsters learning high school science. I heard these kinds of comments in many quarters, ranging from intense, small-group discussions to the address delivered by the Vice-President of the United States. So frequently were such remarks made that I often held my own views in check, fearing that additional support from an organization of science teachers could add little to, but might detract much from the widespread general opinion of laymen.

When you read the final reports of the White House Conference on Education, don't look for specific attention to science teaching. After all, this was an attack on educational problems *in general*. Our discussions were oriented along lines such as the objectives of education, the supply of teachers, and the financing of public schools. I can assure you, however, that the 2000 participants of the Conference—two-thirds of them laymen—were, as a group, vigorously enthusiastic on the subject of more science teaching in the schools of the nation.

Considering the nature of the Conference, it is not surprising that little thought was given to the quality and scope, the content and methodology of science teaching. Surely this is where we, the science teaching specialists, must take over. As teacher-scientists, we have a knowledge of young people and the learning process, and we have a background and interest in science. We must use this know-how to make our maximum contribution to individuals and to society throughout the activity of general and special education. This is our responsibility. This is our privilege.

As my non-scientist, non-educator friend in Washington so bluntly said, "Science teachers are really sitting pretty." There is an expanding public sentiment which permits and demands more science teaching in American schools. It is up to us to insure that we provide not only *more* science teaching, but also *more effective* science teaching.

The challenge is here. In the months and years to come it will multiply—perhaps beyond our wildest expectations. As individuals and as a professional organization, we must be ready for and equal to this task.

Robert Stollberg

President of NSTA

THE SCIENCE TEACHER

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The National Science Teachers Association is a department of the National Education Association and an affiliate of the American Association for the Advancement of Science. Established in 1895 as the NEA Department of Science Instruction and later expanded as the American Council of Science Teachers, it merged with the American Science Teachers Association and reorganized in 1944 to form the present Association.

PROBLEM SOLVING IN SCIENCE TEACHING— A Symposium

This symposium on the problem-solving approach in science teaching developed in a most interesting way. Sheer chance brought three or four contributed papers on this subject to our desk during a two-month period. Meanwhile, the General Planning Committee for the 1956 National Convention chose as the convention theme, PROBLEM SOLVING: HOW WE LEARN. And then the idea struck. Why not "pool" these papers, invite a few others to round out the full range from philosophy through classroom implementation to evaluation, and publish the symposium in the February *TST* as a useful service to all science teachers—and as a form of "homework" for those who will attend the convention? It was just that simple; and here is the full symposium, with a bibliography and an integrating summary for good measure. We predict that this set of ideas and examples for teaching science through problem solving will be a landmark in the literature and frequently cited for a good many years to come. Our sincere thanks to all who have contributed. *Editor.*

Is Science Teaching Scientific?

By ERNEST E. BAYLES

Professor of Secondary Education, The University of Kansas, Lawrence

After almost thirty-five years of active participation in the field of science education, I feel that it may not be amiss to address a few remarks toward what the prevailing outlook in science education may seem to be accomplishing. Although my professional concern for the past two decades has been primarily with the more general field of teaching theory and educational philosophy, my interest in and concern for the preparation of science teachers is no less than it was when that represented my major field of professional endeavor.

What I have to say will be, I fear, less flattering than I would like. For I cannot get away from having it repeatedly and continually borne home to me that the outlook in science education is so engrossed with methodological and curricular details that far too little thought has been devoted to basic theory.

Since the Morrison revolution of the late twenties and the early thirties in which "units" and "unit teaching" almost completely took the field, the situation has been pretty much all quiet on the science-education front. During that time, general-science and biology course-syllabi and textbooks were thoroughly revamped, with the Pieper-Beauchamp general science and the Pieper-Beauchamp-Frank biology taking the lead, all three authors having served on Morrison's faculty at the University of Chicago high school. Chemistry syllabi and textbooks were not as much altered and physics underwent little change. One reason perhaps for physics seeming to be unaffected was that Morrison himself felt that it was already organized on the unit plan and did not require alteration. Why chemistry was no more affected than it was is harder to say. I often feel that it may have been for the same reason that chemists let the physicists take the atom away from them when science got down to real grips with the problem of promoting atomic fission. They did not quite realize how great was the build-up of pressures toward modification of fundamental theory.

What I find depressing regarding emphases in science education for the past quarter-century is the

almost complete absorption in matters such as seating arrangements in classrooms, detailed alterations in laboratory equipment, development and improvement of instructional aids such as visual equipment and demonstration apparatus, improvement of classroom lighting, the planning of new and improved ways for presenting atomic structure as it is now envisioned, acquainting prospective teachers with the details of color television, and scores of other detailed matters which, in military terminology, represent tactics rather than strategy. This is in no wise to say or to imply that tactical details are unimportant or unessential. On the contrary, success or failure in any campaign may and usually does rest upon competent choice and execution of tactical details. By saying that tactical concerns are essential, I mean exactly that. We cannot get along without them.

But absorption with tactical details without benefit of equally competent absorption regarding matters which are basically strategic is a fault of the first order. And that is the fault which I find in the current outlook on science education. Recently, *The Science Teacher* published an article of mine entitled, "Is Modern Science Inductive?" It seems to me that failure on the part of science-education personnel to realize that scientific investigational procedures have today gone far beyond the *Novum Organum* of Bacon and Newton—gathering facts and rendering them general by induction—represents strategic catastrophy. And the fact, that such a large segment of this nation's science teachers and teachers of science teachers feel no concern for this failure and, moreover, virtually fail to comprehend what I am referring to, is exactly what should cause us the gravest of professional concern.

It is high time for us to realize that tested and dependable *theory* is perhaps our most practical possession. For with theory we can deal with myriads of situations never seen before; novel situations wherein we either have to make use of a generalization (which is theory) or we do not handle the situation at all. On the other hand, if one knows only practical details—specific steps to be taken in light of specific situations, then one is powerless when confronted by situations which fall short of being exact replicas of something met before. Probably the most impractical course in science-teaching methods which can be offered is the ostensibly practical one—repeatedly claimed to be practical, at any rate—which is composed of detailed instructions as to what to do the first week, the second, the third, how to present this matter or that, and a host of other particularities. Detailed procedures are thoroughly meaningless if there is no common understanding of what is to be accomplished and of the configuration of circumstances which surround accomplishment. How can you tell me what is the best road, if I do not first tell you where I want to go and what mode of travel I contemplate?

The basic difficulty with so much of our instruction in science teaching is that it is without benefit of overt and conscious consideration, first, of what ends are to be achieved and, then, of a variety of available means which might be employed under the variety of circumstances which are likely to appear. In other words, our great lack is adequate consideration of basic theory. Without theory, instruction on any matter becomes a case of blind leading blind.

What happens when a course in teaching methods is conducted without benefit of overt consideration of over-all educational purpose? Can such a course be conducted at all—one devoid of assumptions as to what the teaching is to accomplish? If such assumptions are not made openly and consciously, they will be hidden, but just as surely at work.

What is the educational purpose that tends to be assumed, and usually is, by a teacher who gives no serious thought to educational purposes? Almost, if not quite, invariably the course becomes one requiring memorization of factual details. Even principles, such as Boyle's Law, are treated as something to be memorized. In classroom physics examinations, for example, practically never are examinees given opportunity to use handbooks, charts, or notes to refresh memories on exact formulae, physical constants, or other factual details, in order to compensate for memory lapses. Nor is thought given by the examiner toward differentiating between failure to answer a question because of memory lapse and failure because of lack of understanding. Moreover, during instruction it is only occasionally, if at all, that attention is devoted to the manner in which a formula was or can be derived so that, in case of memory lapse, an examinee might be able to retrieve himself somewhat by rederivation.

Memory, memory, memory! Even though we resent being dubbed fact-mongers, as a profession we are exactly that. A quarter-century ago, Ellis C. Persing reported a study in Cleveland. He asked a group of science teachers to write down their teaching aims. He then went to the source which is a sure mark of what teaching aims actually turn out to be—examinations given by those teachers. As is the examination, so is the instruction; for students are wise enough to seek in a

(Please continue on page 63.)

The Science Teacher and Problem Solving*

By OREON KEESLAR

Coordinator of Secondary Curriculum, Santa Clara County Schools, San Jose, California

The subject of my talk this afternoon—the scientific method of problem solving—is evidently a controversial issue. As I see it, the controversy hinges about three simple and basic questions: Is there such a thing as scientific method? If so, can it be taught? And furthermore can it be applied to human problems outside the realm of the sciences?

Obviously there is such a thing as scientific method, if we can only manage to identify a *common, procedural pattern* among the many problem-solving methods of successful scientists, and if we then agree among ourselves to call this general pattern of action "the scientific method." But scientists are not stereotyped in their methods. Their approaches to their problems are endless in their variety. In fact, one would be justified in saying that there is no such thing as THE scientific method—there are only many, many scientific methods, varying in their steps according to the nature of the problem, the conditions and exigencies under which it must be solved, the background and immediate aims, the thoughts and "hunches" of the investigator, and many other factors.

Should we then drop the use of the term? I do not think so. We can identify and abstract quite a number of common techniques and devices, customarily employed by scientists in their work, which are more or less standard elements of their methods and completely in harmony with the spirit of science. These "tricks of the trade" have been developed and refined in practice through the last two or three centuries by pioneering scientists who were trying their best to profit from their own mistakes. I refer to such aspects as: [1]

—carefully identifying a problem
—forming hypotheses
—relying on experimentation rather than guesswork for facts
—introducing a control, to isolate the experimental factor
—making careful and appropriate measurements of the variables
—repeating and varying procedures, as check experiments

[1] Keeslar, Oreon, "The Elements of Scientific Method," *Science Education*, XXIX (December, 1945), 273-278.

The items in this partial list are elements of method, pure and simple, but behind them lies the mind of the investigator, which in the end will determine whether any method used will yield results that are valid and trustworthy. Knowledge of the method alone is not enough.

What, then, are we going to do about teaching scientific methods in the classroom? I believe a clue is to be found in the writings of two men in whom I have a great deal of confidence. John Dewey once wrote: [2]

> One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit.

I am sure this statement voices the convictions of many of us—but Dewey was not a scientist. He was an educational philosopher who was deeply interested in how people think most effectively. So it is interesting to hear what a top-ranking scientist has to say about the teaching of scientific methods.

In his excellent book, *On Understanding Science*,[3] James B. Conant undertakes to reconcile the conflicting views of whether scientific methods can, or should, be taught. He maintains that the scientist alone should not be put up on a pedestal as an impartial inquirer, that the best examples of scientific thinkers may well be found in non-scientific fields. He acknowledges the scantness of evidence that scientific methods can be transferred with advantage to human activities other than science, but recommends that this be tried for the good of mankind.

To implement the recommendations of Dewey and Conant, I suggest a definite shift in emphasis

[2] Dewey, John, "Science and Democracy," *Scientific Monthly*, LII (January, 1941), 55 (from *The Scientific Method and Study of Processes*).

[3] Conant, James B., *On Understanding Science*. New Haven: Yale University Press, 1947, pp. 8-11.

* From a paper delivered at the Western Regional Conference of the National Science Teachers Association at the University of California, Berkeley, December 28, 1954.

in our teaching of this important aspect of science. First, let us accept the true premise that there is no one method of solving a problem which can be called *the* scientific method; let us cease to think of scientific method as a prescribed series of steps in problem solving, which our students must memorize in order to pass a course. Instead, let us concentrate our efforts deliberately and with renewed energy on the development of a *scientific habit of mind* in our students—the scientific attitudes,* if you please. Let us concentrate on teaching the *spirit of science,* as exemplified by such attitudes as:

—desire to try things out experimentally
—belief in cause-and-effect
—rejection of superstitions as a basis for thinking
—determination to be careful and accurate in all one's observations
—willingness to change an opinion or conclusion because of later evidence
—determination to be objective in judgment
—unwillingness to base a conclusion on one, or a few, observations

Then in problem solving, let us anticipate the human element and welcome *original methods* for each problem situation, but hope that these incorporate such of the best elements of scientific methods as the situation warrants. The important thing is not the pattern of method *per se,* so much as it is the spirit, or habit of mind, of the problem-solver. I believe acceptable methods will very likely result, if the spirit is right!

Then how can we inculcate this scientific habit of mind in our students? It seems to me we must deliberately forego the conventional classroom practices of lesson-hearing and recitation, entering instead into an entirely different student-and-teacher relationship, in which the student's manner of *thinking* and *believing* and *reacting* becomes our chief concern. In this approach, it is our function as good science teachers to lend expert guidance to students *while they are attacking and solving real problems!*

At this point, I fear, unskilled teachers are often trapped into sabotaging their own best interests as teachers. The student wants an answer to his question—wants it without undue delay, and if possible, without much effort. The unskilled teacher responds to the flattery of a direct question from a student by telling all he knows—and that is usually quite a lot! It is more than enough, certainly, to wreck his chances of ever directing the student through a scientific method of problem solving—that soul-satisfying experience of solving a problem with just what the student himself brings to it.

* An attitude may be defined as a predisposition to act in a certain way whenever a given situation occurs; it may have its origin either through prejudice and ignorance, or through rich experiences thoughtfully provided by skilled teachers.

Drawing thus upon past experiences for greater insight into a puzzling situation is one of the prime elements of any method of solving a problem scientifically, but you need not point this out to the student every time it happens. It is enough if you lead him through the process time after time, until it becomes second-nature for him to wonder, to look, to think and recall, to speculate, and to try out. He is then on his way to thinking scientifically.

But if you aren't going to tell him all his answers like a walking encyclopaedia, what will you be doing while the student is delving into his problem? To be a skillful teacher, you must join him in his wondering. You show him that you are really interested in what he thinks. If he has trouble putting his ideas into words, you help him. You ask him questions, while the eyes of both of you are on the problem. You watch for clues as to how the student's mind is working, the things he is seeing in the situation, the things he isn't seeing when he should, the evident errors in perception and reasoning. You get the *measure of his mind,* and key your teaching to the level of his maturity and experience, which you accept without embarrassing condescension. You try to keep that vital interest up, and prevent any overwhelming sense of frustration from killing the student's self-confidence and drive. You encourage him to test his ideas experimentally whenever feasible. You lend a helping hand where it is really needed—perhaps by pointing out something overlooked, without which a solution is impossible, or by throwing in a leading question or observation—and you subtly guide and sustain the problem-solving process through to a successful conclusion, if that is possible. Of course, it would save time for both of you if you told him at once what he wanted to know; but then—there would be no problem, that first requisite for teaching scientific methods!

By the way, I am pretty well convinced that very little problem-solving method is taught in the conventional high-school science laboratory! Certainly the motivating drives there are not real-life ones, since the problems are not naturally arrived at and formulated by the students, and in many cases are not clearly understood by them. All too frequently there is no real problem involved at all —except to "get the right answer." In fact, I once overheard one of my own students in physics lab

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ELEMENTARY SCIENCE

Effective Learning Through Science Investigations*

By JULIAN GREENLEE

Professor of Education, Florida State University, Tallahassee

It seems reasonable to believe that we achieve at our highest professional level when we provide instruction and opportunities for learning at a level appropriate for the pupils with whom we are working. Both content and procedures should be selected in terms of our pupils. Instead of helping our students adjust to a strange mysterious world, we should help them as they grow in ability to master their world. This, I submit, is acceptable philosophy for all science teaching from kindergarten through the general education program in college.

We, as science teachers, have perhaps a better opportunity to take the lead in improving instruction by discovering and applying the best teaching processes than do instructors in other areas. Our teaching content is conducive to experimentation with different teaching procedures. Our background of science information and methods is unique in our profession.

Is it not as important that we apply our best information and techniques in arriving at the best teaching processes as it is to apply them in getting science information by research, including experimentation? Many of my former science professors were eminently successful scientists, carrying on important research studies, continually striving to get new science information. However, these activities were forgotten when they came into the classroom. I believe that the professors made too much distinction between research and teaching. In getting new information for themselves, they followed the best techniques; but in teaching they generally *told* us. Education was a one-way process. They gave us the information and we took it. During all of these classroom experiences, I didn't, except in "research courses," have the opportunity to apply a scientific approach to a single science problem with which I was concerned. Let us, as science teachers, not make the same mistake with our pupils.

At this point you may say, "Fine, it sounds good. How do you do it, particularly at the elementary school level?" We are sometimes misunderstood when we say that teachers must be willing to learn as their pupils learn. We surely don't mean that teachers have no need for definite information. We mean that teachers must not permit the lack of information in an area important to the pupils, to prevent them from taking up studies within that area. Attacking and finding the solutions to some problems of concern to the pupils ought to be a part of every science course. This is quite different from teaching a prescribed course outline or syllabus. We cannot justify teaching aimed solely to meet the hypothetical needs of a science content area.

A scientific method of investigation is a natural way of learning. Little children, as they go about their business of orienting themselves to their environment, apply a method that is not unlike that of the research scientist. Of course it is at a different level and deals with a different type of content. Any parent will probably remember some of the ways in which little children learn. For example, consider an experience of bathing the baby.

> The baby sits watching the stream of water fall into the tub. He reaches out for the stream, closes his fingers, and brings his hand back to himself. He looks and the stream is still where it was. He looks in his hand and it is empty. Again he reaches for the stream. This time he is very careful so as not to miss it. The results are the same.
>
> The baby changes his tactics. He carefully reaches his fingers around the stream of water, quickly closes, and pulls his hand away. Still the stream is where it was and his hand is empty. (The baby continues for some time, trying first one technique and then another.) A raveling hangs from a towel. The baby reaches over, takes the raveling in his hand, and examines it. While holding it he looks again at the stream of water. The baby again tries to get the stream of water in his hand. Then he stops trying for this day.

The baby doesn't have a vocabulary with which to communicate his questions and his conclusions. One can only surmise as to what he is thinking. It seems reasonable to assume that he expects to pick the stream of water up in the first place, that he

* From a keynote address given at the Midwestern Conference on the Education of Teachers in Science, Cedar Falls, Iowa, March, 1955.

then wonders if he is right about strings, and that he experiments to the extent of comparing the string with the stream of water.

Little children are quite persistent in their investigations. We hear much about how short their interest spans are, but I wonder about it. They will come back to the same problems day after day as they pursue some interest. Their interests in some of the things adults want them to be concerned with may be short, and certainly they should not be kept for long periods of time at activities which to them are monotonous and pointless. However, I have an idea that if we knew more about the ways in which children learn, we could improve our own skill in working with them and with older pupils in science classes. Let's move up to the age level of a five-year-old.

> Laura came excitedly to the kindergarten teacher. She said, "I have found out what makes sand." Laura carried a brittle sandstone, a piece of granite, and a jar in which she had some sand. She said, "I made this sand by myself and I will show you. Do you have a newspaper?" She spread the paper on the floor, laid the granite on it, and said, "Watch this," as she rubbed the sandstone against the granite. As some of the sand was rubbed off, she said, "I made this," indicating the sand in the jar, "the same way. People don't make sand, but the rocks do." Laura explained that she had found the sandstone and the sand. She had thought that the sand looked like it came from the stone and she tried it and then she was sure.

I don't mean that Laura had learned all about sand. I do think she had learned something about it. Apparently she had established an hypothesis and then devised the experiment for determining whether she was correct. When she decided that she was, she wanted to share her glory with others, just as one of us would.

Let me describe a classroom experience with third-grade children.

The children in Mrs. Monroe's room were studying "time." They had decided that there were many ways of knowing when it was lunch time. They could tell by the clock in the classroom, the bell that signaled the end of the morning, the shadow that fell along the crack in the floor, and the fact that they were just about as hungry as they could be. When Mrs. Monroe was planning the manner in which she would stimulate an interest in the study of sound, she became aware of another lunch time signal, the factory whistle.

One day as lunch time was approaching, Mrs. Monroe said, "Children, I know of another way in which we can tell when it is noon. Let's be real quiet and listen after the bell rings." The bell rang. Every one was still, listening. Then they heard it, as the factory whistle blew.

When the children came back to the room following lunch, Mrs. Monroe said, "Let's be real still and see how many different sounds we can recognize." The children heard a jet plane, a truck, an automobile, a motor scooter, a mocking bird, a robin, a dog, people walking and talking, the wind, a bus, and water running in the lavatory. Marjorie said, "Everybody is so still. We could really hear the factory whistle if it blew now."

Mildred said, "I used to hear a whistle, a real loud one where I lived last year. My grandma lives there now. I wonder if she can hear the one we heard today." Floyd said, "Gee, I don't think so. That's about ten miles away, but why don't we listen and see if we can hear the other whistle, the one that you used to hear?" Mrs. Monroe hadn't expected to get into this kind of an investigation. However, she thought of it as having worthwhile possibilities for the children. She remarked, "We could listen for it tomorrow."

Mrs. Monroe told the children that even if the other whistle was blown at exactly twelve o'clock they would not hear it then, because it would take the sound some time to come that far. She didn't remember just how fast sound traveled. Lloyd said, "Couldn't we look it up in a book or couldn't we ask Mr. Mitchell, the high school science teacher? I think he would know that." Mildred said, "Can I find out about it? I can look it up in the encyclopedia."

Mrs. Monroe said, "You might find it in the encyclopedia. What are some of the other places where we might find it?" Chris said, "If we know how far it is away and if we know what time we hear it, and if we know what time it blows, couldn't we find out how fast it travels? That could be an experiment." Dwight said, "I think we could do it that way. We could find it in a science book of some kind in the library and I think maybe we could find it in the encyclopedia."

By this time Mildred had gotten the encyclopedia and found the discussion about sound. She brought the book to Mrs. Monroe saying, "I think maybe it tells it here." Mrs. Monroe took the book and said, "I'm sure you are right, Mildred, but I think we might look it up in some of the books in the library, too. It isn't in our science textbook. Do you want to go to the library and get a physics book and a book on physical science for me? We will read about it in all three books. Say, Mildred,

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A Problem-Solving Approach in Biology

By IRENE HOLLENBECK

Assistant Professor of Science, Southern Oregon College of Education, Ashland

To help high school biology students develop an understanding of the scientific method and its importance in our lives today we should make use of a variety of activities. We need to develop the idea that the scientific method is not a rigid step-by-step procedure but a pattern of behavior that develops when individuals seek the solution to a problem in a systematic way, and that, like all patterns, it may be altered to fit any situation. We also need to see that every student takes an active part in the use of these methods; it is not enough to study about them.

Consequently, as part of our preview of biology on the first day of school there are a number of problem-solving activities about the room. Perhaps the one which arouses the most interest is a drawing on the blackboard which tells the story of a murder mystery, a murder committed on a dusty meadow road. Drawings of tracks of birds (a mother pheasant and her young, a song sparrow, a robin, and a flicker) and of rodents (rabbits and squirrels), together with symbols representing bushes, trees, and a struggle in the dust of the road, tell the story of life in a pleasant little community suddenly and tragically interrupted by the advent of a predator. On the blackboard near the drawing are such questions as: "Who was the murderer?" "Who was the victim?" "Did he leave any close relatives?" "Who were the witnesses?" Students gathered around this drawing on the first day of school often get into heated discussions. The next day the first subject they want to discuss is this "puzzling situation." It seems that not all were agreed upon the characters in this drama. This very situation gives us an opportunity to set up a problem, collect all the evidence in the case, and start making "guesses" as to what actually happened in the meadow. Students usually suggest: "I think a hawk flew in and caught a rabbit." "Could it have been an owl after a bird?" "Maybe a snake came up out of the ground." "Perhaps a bear came out of the bushes." It then becomes necessary to select one of these guesses as a hypothesis and to obtain more information. Books and magazine articles are provided that have good diagrams of bird and animal tracks and by examining these and by reading about the habits of the animals in question we are able to substantiate or disclaim our hypothesis. Not until the students have had the fun of playing with this puzzling situation do we show them how they have been working with the basic elements of the scientific method. This activity is not only fun but an easy way to learn a few of the steps in solving problems. At this time we also point out that much of our work in biology will be spent with just such puzzling situations as they arise, with asking questions about our environment, and with devising ways to find the answers to our questions.

Not long after this introduction one year a question of immediate concern to some of the students in my biology classes did come up. One of the boys asked, "Why is trout fishing so poor in the stream that crosses our campus?" Again we had an ideal opportunity to discuss the scientific method. It was important that we state our problem carefully, make a number of "guesses," and start collecting data bearing on our problem. This time the collection of data included making and recording accurate environmental measurements, interviewing authorities on trout, reading in the library about trout and their needs, comparing this stream with one known to have better fishing, and viewing a motion picture on trout. When all the data were in we were able to formulate a tentative answer to our problem.

All through the year, whenever a student asks a question and it is possible to discover the answer through experimentation, we take the time to plan in class. It may mean that we do not cover as many units as other classes, but we do gradually gain a better understanding of the ways of the scientists. One day, during a demonstration dealing with photosynthesis, a student asked, "What would happen if you added more carbon dioxide to the air around that plant?" Predictions came quickly: "The plant would grow faster." "The plant would die if entirely surrounded by carbon dioxide." This time, after considerable class discussion and planning, the problem was turned back to the student who

asked the question. He worked on it as a project, devising his own system of measuring the carbon dioxide and the growth of the plant. He soon saw the need for a control. And, knowing that he was expected to report back to the class the results of his experiment, he saw for the first time the need to keep accurate records. Up until this time he had been a somewhat reluctant student (biology was required) who thought that keeping notes on experiments was a waste of time. The challenge of the unknown and the thrill of discovery changed his entire attitude toward science—it became his major in college.

A second way we help students gain an understanding of the scientific method and of scientific attitudes is to use the lives of scientists to show that they have been and are now seeking for clues to biological phenomena in an exciting variety of ways. I have found that the story of Paul Ehrlich's intense interest in dyes and his idea of chemical affinities as the keys to life's mysteries can fascinate an entire class. While we are studying a unit on microbiology or one on health and disease I take the time to read to the class from *Magic in a Bottle* [1] the story of Ehrlich found on pages 7-137. We also view the film, "The Magic Bullet." [2] Both tell in a vivid manner the story of his exciting discoveries. Pasteur's discoveries offer equally absorbing reading and viewing. We like especially the "Anthrax sequence" from the film, "The Story of Louis Pasteur." [3] During this unit, and others when we read from some of Darwin's works or from Mendel's [4] own account of his investigation of garden peas, students begin to see certain habits of thought common to all scientists crop up time and again: a desire to try things out experimentally, careful and accurate observations, an unwillingness to base a conclusion on one or two observations.

Today's scientists are working on projects just as exciting as those of Mendel, Darwin, and Ehrlich. Students are intrigued with the story of Selman Waksman, the microbiologist who puzzled over the fact that the soil had so few disease-causing bacteria in it despite the fact that so many could have gained entrance. They are surprised to learn that as a result of his experimentation with soil and bacteria, he finally isolated the antibiotic, streptomycin. As they become interested in current science they bring in newspaper clippings and make reports to the class of even more recent scientific discoveries. Sometimes this activity takes the form of a bulletin board highlighting current research.

One of the oldest and best known methods of science is that of observation and description. When students are introduced to the teeming microscopic life in a drop of pond water, one of the first questions asked is: "What are they?" We point out that knowing the name isn't nearly so important as the ability to describe them so accurately that other students will be able to recognize the same animals under their own microscopes. This, again, involves careful observation and accurate reporting to other members of the class. Toward the end of the laboratory period we read to the class Leeuwenhoek's account of his first observation of rainwater from *Readings in Biological Science*.[5] Students marvel at his accurate descriptions and realize they have just been looking at some of those same animals.

Field trips offer further opportunities to observe, to ask questions about the environment, and to look for reliable explanations of the phenomena observed. On one fall field trip a boy picked up several oak leaves bearing insect galls and asked what they were. It was suggested that we look inside and find out. Each member of the class collected a half dozen or more infected leaves. By working in groups we soon "discovered" the life cycle of a fly. But was it a fly? Powers of observation were not yet well developed and it was necessary to take a closer look to find the four wings of an emerging wasp.

On another field trip we looked for evidence that might explain some of the following questions: "Would this forest be a good place to go deer hunting?" "Why are there more birds on the edge of the forest than down in the canyon?" "Why are the trees in the picnic area so spindling?" "Would you expect to find trout in this stream?" On this same trip each squad of students selected a special habitat to explore. One group of boys chose the pool at the base of a falls. Here they noticed snails and insect larvae that were different from those in the stream on the campus. "How come?" They sensed a problem! It was most satisfying to listen to them plan their procedure and set up a system of collecting data, and to realize that here at least were some students who had grown in their understanding and use of the scientific method.

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[1] Silverman, Milton. *Magic in a Bottle*. New York: The Macmillan Company, 1951.

[2] A condensation of Warner Brothers feature film, "Dr. Ehrlich's Magic Bullet." United States Public Health Service.

[3] This and the hydrophobia sequence from the same film are obtained from Teaching Film Custodians, Inc., New York.

[4] Mendel, Gregor. *Experiments in Plant Hybridization*. Cambridge, Massachusetts: Harvard University Press, 1950.

[5] *Readings in Biological Science*, Irvin William Knoblock, editor. New York: Appleton-Century-Crofts, Inc., 1948.

Problem Solving in High School Physical Science

By HAROLD E. WARD

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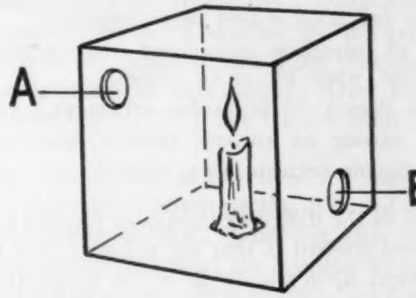
The typical demonstrations and laboratory experiments often have little to offer in developing the problem-solving skills. True, the exercises are essential for the development of scientific concepts; yet in many cases the conclusions are obvious, and in some cases the exercise proves nothing. For example, a few months ago a group of my students were performing a workbook exercise to determine the products from the oxidation of fat. The directions for the exercise left little doubt as to the desired conclusions. The students were instructed to make a candle from lard or butter and ignite it. After the candle was burning, they were to place, first, a white saucer and then a cool beaker in the flame. The students followed directions and all of them drew the conclusion that burning fat produced carbon and water. The next day I asked them what they had discovered and listed their conclusions on the board. I then repeated the exercise asking them to observe carefully. After the exercise was completed, I asked them again to write their conclusions. One young man put it very well when he said, "The exercise showed that burning fat produces something black, and that water from somewhere collected on the beaker. I'm not sure it came from the oxidation of hydrogen in the fat."

Often, the students spend too much time trying to find out what the exercise is supposed to "prove" rather than analyzing the exercise to determine what evidence it actually provides. Why? Because they have not developed some of the problem-solving skills, and because the exercise is someone else's.

There is no doubt that many high school students are naturally curious; they like to discover things. And they *can* develop methods for solving problems. Yet, in spite of this, some of us do most of the explaining and most of the demonstrations, in addition to requiring the students to do "canned" exercises. Though students sometimes get off on the wrong foot in an investigation, there is benefit in their finding that they are wrong. I know a young man who satisfied himself that horsehairs did not produce snakes by trying to prove that they did.

Following are some problems from high school physical science that my students have found worthwhile.

A. One of my favorite problems originated from a convection box as shown in the sketch below. To set up the problem, I perform a silent demonstration. I light the candle inside the box and hold the flame of another candle at opening B. The candle inside the box is extinguished. I appear surprised and repeat the action two or three times.



Then I hold the flame of a candle at A. This time the candle at A is extinguished. I instruct the students to make hypotheses as to why the candles were extinguished. The most frequent ones offered are:

1. Currents of air extinguish the flame.
2. Products of one flame extinguish the other.
3. One of the candles removes something from the air that the other one needs to burn.

At this point I could kill the suspense by explaining the occurrence; however I encourage a series of investigations, the results of which may provide a solution to the problem of the convection box. To set up the investigations, we discuss and list the things we need to know to solve the problem. Some of the ones usually suggested are:

1. What are the conditions necessary for burning?
2. What are the products of combustion?
3. What happens when air is heated?
4. Does the movement of air affect a burning candle?
5. What happens to a flame when the supply of oxygen is cut off?
6. Will carbon dioxide extinguish a flame?
7. How may one test for carbon dioxide?

After the discussion, the students carry out a series of exercises to find answers to the questions which will help solve the problem of the convection box. Some students plan their own exercises, while others get help from textbooks and other sources.

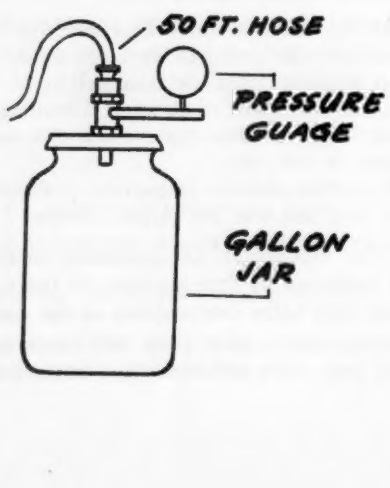
When the students have concluded their activities, we go back to the convection box to explain what happened. Usually a suitable explanation is offered, yet qualitative tests need to be done on the gases in the box to verify the explanation.

During the progress of this problem, other problems are encountered. Thus, other investigations in heat and temperature become outgrowths of the original problem. Some of these are:

1. In what form is tallow when it burns?
2. Can a fire be extinguished by controlling air supply? by controlling temperature?
3. Are the kindling temperatures of all substances the same?
4. How can gasoline fires be extinguished?
5. Do all substances expand and contract the same amount when heated or cooled?
6. How does a candle snuffer extinguish a candle?
7. Do moving air currents transfer heat?
8. Do liquids circulate when heated?

B. One of the difficult concepts of physics for the high school student is that the pressure of a liquid is dependent upon the depth of the liquid and not the amount of liquid or the shape of the container.

The problem may be introduced by displaying containers of equal height but of varying diameters and shapes. The students are asked to predict which of the containers has the greatest pressure at the bottom. After the predictions are made, they are discussed in terms of the text statement that liquid pressure depends only on depth and density. Some students take issue with the statement. I then ask them if they can devise an apparatus to test whether the statement is right or wrong. Recently, a group of students constructed a device as shown in the diagram to show that liquid pressure was not dependent on depth; yet, as a result of their own experimentation, they became convinced that liquid pressure is directly proportional to depth. Further



evidence of this fact may be obtained by varying the size of the tube above the jar.

C. Another group of problems that students can solve for themselves deal with the study of simple machines. Although some of the students need careful direction in work with simple machines, others profit most from exercises which they themselves develop to solve the problems of simple machines.

This series of problems is set up by group dicussion after a brief introduction to simple machines. During the discussion these question usually arise:

1. What is mechanical advantage?
2. How may one determine mechanical advantage?
3. What is the relationship between work input and work output?
4. What is the relationship between effort force and resistance force?
5. How does a machine give mechanical advantage?

Some of the students by means of self-designed exercises solve the problems of simple machines, others need some help and direction, while others need a "recipe."

Following the periods of experimentation, the students meet to report on activities, problems, solutions, and conclusions. Usually, those who have done the most real problem solving have the best understanding of the scientific principles involved. During the progress of the problems described above, the students are encouraged to look for new problems, to define them, to make tentative explanations, to test the most likely ones by experimentation or research, and to draw a conclusion or conclusions.

Problem-solving techniques have not been a cure-all for my problems in teaching science, nor have they insured universal interest in science; yet, permitting the students to use whatever abilities they have or have developed for problem solving, and encouraging the growth of skills through problem solving will insure a deeper understanding of science and the methods of scientists.

Do Their Scientific Methods Show?

By OREON KEESLAR

Coordinator of Secondary Curriculum, Santa Clara County Schools, San Jose, California

As science teachers, we are all hopeful that our students will become good thinkers while studying science with us, and will begin to use scientific methods more or less habitually in meeting everyday problems. We—many of us—have guided them through what we think they need to experience to become intelligent users of scientific methods. Perhaps eventually we have talked to them about hypotheses, experimental factors, controls, allowable margins of error, test experiments, conclusions, and many other terms now commonly used in discussing the technical aspects of problem solving. But how can we know that any of these ideas have "taken" in their minds?

Several types of paper-and-pencil tests were devised about fifteen years ago by Tyler, Raths, and others in connection with the famous Eight-Year Study of the Progressive Education Association. These tests get at the gullibility or conservatism of students in interpreting data or in applying scientific principles, and will provide a teacher with some clues to his students' habits of mind. But their usefulness has evidently proved to be somewhat limited, since after all, they are paper-and-pencil tests, and assess the students' *methods* of problem solving only superficially and most indirectly.

Therefore, if we are to evaluate more directly (and I think we should), how are we going to do it? I believe the proof of the pudding is in the eating: We should watch our students' behavior as they meet everyday problems. We should study their manners of thinking, and their attitudes toward people and things. When an important question arises, we should watch to see how each individual meets it—and I believe I would be satisfied at the beginning if there were METHOD of any sort in the individual's way of attacking the problem, whether it matched my own notion of good procedure, or not.

To illustrate: A junior class committee under my sponsorship is decorating the Community Recreation Hall for a school dance. Emily and Joyce are endeavoring to fasten large decorative plaques of cardboard and crepe paper to the walls with masking tape. As I enter the room, I see that they are in difficulty.

Emily turns to me in despair and throws out her hands, "Look, Mr. Keeslar! This tape just won't stick! It keeps peeling off after a while, and everything falls down. What are we going to do?" Her voice rises to a wail. ***"They won't let us use nails!"***

You see? For her, the tape will not hold, they won't let her use nails, and that is where the matter ends. She turns to me for a ready-made solution to her problem. The other girl has paid scant attention to me, however, and I see that she is still busy, examining the tape closely. Over her shoulder, I hear her say, "I'll bet I know what's wrong, Emily!"

This, believe me, is the time for me to keep quiet! Although I recognize the gleam of scientific method coming through, I do not stop Joyce to point out to her that what she is about to propound is called a ***hypothesis***. It is enough that I alone, as her science teacher, realize that this is happening.

Joyce shows us that each place giving them trouble is over a floor-furnace register, and that the sloping window-sills and the walls above are heavily coated with dust and lint. In moving the decorations here and there for best effect, the tapes had lost their stickiness in a coating of lint.

"Now, look," she continues, stripping another short piece of tape from the roll. "This is fresh and sticky, see—but when I put it on the wall up here and peel it off a couple of times, it doesn't stick so good any more!"

I feel a gratifying glow at the way she goes after the problem, but I realize that she has not really tested her hypothesis. She has simply re-demonstrated the troublesome behavior of the tape, collecting a little more evidence to support her hypothesis, and establishing a control.

"Now," she goes on, "suppose we just scrub all the dirt and fuzz off the wall here with a damp cloth. Then we'll see whether a fresh tape won't stick better." This is done, and the tape holds—much to Joyce's pride, and mine as well. Even though the plaques fall down again that afternoon and the girls have to switch to an entirely different mounting technique, this does not lessen my satisfaction in the way the problem has been handled.

In reviewing her method, I could identify these elements: She sensed a problem; she determined to do something about it (at this point, she and Emily

parted company); she made a close examination of the surface of the tape which had failed, and of the wall to which it would not stick; she made a good intelligent guess as to the cause, drawing upon all her past experiences with *stickiness;* and then she tested that hypothesis in a situation which actually involved a control.

As her science teacher, should I have urged her to run check experiments as a logical subsequent step in scientific method, or write out a carefully worded, strictly valid conclusion, based on her evidence? *I should say not!* For, you see, the girls still had a room to decorate, in spite of the troublesome tapes, and that job just *had* to be done! You know how terribly important such things can be! I would have won no friends and influenced no one, if I had broken in just then with a scholarly harangue on the fine points of method I identified in the situation.

The scientific method was for Joyce simply the best means she could see to an end that was valuable to her. She was demonstrating the scientific habit of mind of which John Dewey and James B. Conant have spoken so highly, but for her it was not a highly abstruse, intellectual exercise of a method pursued for its own sake. It was the most sensible way she knew of working out a solution to her problem. That she could not have identified the control she used in this situation to save her life doesn't bother me. I had watched her enough to know that this way of thinking and acting was becoming habitual in Joyce's life, and that is what pleased me.

After she has experienced the effectiveness of scientific methods in successfully solving some of her own problems, then—and not until then—would I be ready to help her abstract and verbalize the technical aspects of what she has done. The *experience* really must precede the *word* to make it meaningful! And, moreover, it is the *habitual behavior* of the student, rather than his verbalism on the subject, that counts.

This, it seems to me, is approximately the right plane on which to treat scientific methods with high school students.

February Reminders For NSTA Members:

1. Mail your ballot for officers and directors for 1956-57 to Ned Bryan, Rutgers University, New Brunswick, N. J.
2. Make your hotel reservations for the Convention directly with the Shoreham Hotel or other hotel of your choice. Bring the whole family; let them "sightsee" the Nation's capital.
3. Return to NSTA headquarters, the advance registration form which will reach you the week of February 13.

The Challenge

By PAUL L. DRESSEL

Head, Board of Examiners, Michigan State University, East Lansing

Someone once remarked that if you make people think that they are thinking they will love you, but if you really make them think they will hate you. This easy generalization is no more than a half-truth. Every adult who has had contact with children has experienced the devouring curiosity of the young—a curiosity too often stifled by the understandable impatience of the adults who find it expeditious to give a pat answer rather than to encourage exploration designed to reach an answer. Not infrequently the adult's impatience is whetted to a fine edge of irritation by uncertainty as to the adequacy of his own pat answer. Seldom would any teacher or parent wish deliberately to discourage thinking or problem solving on the part of any child, but a variety of forces conspire to make us do just that. Despite the interest manifested by many teachers in cultivating in their students what is variously called the scientific method, the scientific attitude, critical thinking or problem solving, it is not surprising that actual accomplishment leaves much to be desired. The difficulties to be overcome are numerous and complex and the situation will not quickly be remedied.

Scientific knowledge is increasing at such a rate that science courses can scarcely keep up with it. Into the elementary courses more and more material is being crammed so that the reading rates of teacher and student alike are often taxed by the apparent necessity for covering it all. In the face of such coverage, understanding is difficult to achieve; the acquisition of ability to do original thinking is impossible. Time is essential if students are to arrive at conclusions based on their own thinking. Most teachers realize and exhibit concern about this, but there are a few teachers who seem to believe that ability to think is the inevitable result of assimilation of significant factual knowledge. For such teachers and their students there is little hope. Most teachers wonder to what extent planned cultivation of thought processes is within the power of the teacher. For their doubts we must have great sympathy. We have also the hope that, given the evidence that improvement in problem solving is possible, these teachers will do something about it even if it means reducing the number of topics covered.

The teacher who wants to emphasize student problem solving finds difficulty in so doing. When, in seeking aid, he turns to reported examples of student ventures in the scientific method he may find that they read too well. It is difficult to visualize the individual student or a class working through to a solution of a problem as expeditiously as is implied by the usual thumbnail reports or by the suggestions for classroom or laboratory procedure. The enthusiastic but unwary and inexperienced teacher who tries the same idea—such as those suggested by Greenlee and Hollenbeck in preceding papers—may have some embarrassing moments. The resulting disorder and disorganization is enough to convince the teacher that "it can't be done." Considering the nature of teacher preparation, this result is not surprising.

Prospective teachers are taught subject matter. What they learn about instructional methods is commonly in isolation from their major subject and largely irrelevant to the way this subject was taught to them. The would-be teacher gets little insight into his own thought processes or those of others. He is largely ignorant as to ways to stimulate students to think and is unable to focus on the process of thinking as separate from the results. Quite naturally, then, the teacher finds it difficult to so plan a class that the individual students are encouraged to think for themselves.

All these points have been made or covered in some way by the authors of the preceding papers. Excellent suggestions have been made also as to ways of developing problem-solving skills. In the main, only those already convinced read such papers. Teachers in larger numbers must be convinced that teaching can be oriented to the fostering of thought and they must be given a clearer idea of the characteristics of instruction and of the classroom in which students think rather than memorize.

In some recent work with teachers in Michigan we have developed two lines of thought which seem to hold promise. One of these involves the use of recordings of the discussions of a class over a period

of several days. In contrast with the glowing over-simplified reports of student thinking, listening to the discussion of an actual class provokes greater interest in teachers. They can hear the false leads of students and see that these are not necessarily a waste of time and may be, indeed, a necessary preliminary to more critical thought. They can hear the inappropriate responses of the teacher and note the skill of the teacher in drawing out and developing the more significant lines of thought. If the class chosen for such recording is handled by a skilled teacher dealing with materials commonly covered in most classes, greater insight into what most teachers might reasonably be expected to achieve can result. If the recording covers several class periods, the increased student involvement and actual improvement in the thinking done becomes apparent.

In the process of preparing for the making of such recordings, we found that it was not enough that a teacher planned to use a problem-solving approach for the next several days. In such circumstances the class was likely to result either in chaos or in a lecture. However, when the general topic to be treated in class over several days was carefully read and discussed several times in advance of the first class period, it became possible to list a variety of questions, problems, and possible modes of exploration to the point where the teacher could sense the significance of student comments that might have been otherwise ignored. Assignments from the text encouraged memorization of textbook statements whereas clarification of the problem and the voicing of hunches about it placed the text in the light of a resource for checking on these ideas and for seeking new points of view. The problem-solving class requires much more preparation on the part of the teacher than does the usual textbook reading and recitation approach. The teacher must assume a less obvious directive role but actually a more challenging and more exacting role in drawing out the students. Thus, education takes on its original and most significant meaning.

A commonly voiced demurrer in regard to problem solving or critical thinking is that it is only one of many educational objectives. Attitudes, values, factual knowledge, interests, appreciations, and others are expressed as concerns which may be lost in the emphasis on the intellectual processes. Our experience in recording of classroom discussions indicates that such fears are groundless. The more that students think and interact in their thinking, the more apparent it is that all other educational outcomes are involved in meaningful ways as individuals come to grips with problems that have assumed some importance to them. Education in a democracy cannot justifiably seek to inculcate attitudes or values but must rather encourage adherence to those deemed best for individuals and for society after careful and critical examination of the alternatives. Formal education can never provide the individual with all the knowledge and skills he will later need. Formal education should be only the beginning of the education of each individual. His further education depends on his ability to think for himself. The true value of any course must be measured by the extent to which it develops this ability.

Obourn New U.S.O.E. Specialist for Science

On December 19, 1955, Dr. Ellsworth S. Obourn assumed the duties of Specialist for Secondary School Science in the U. S. Office of Education. The post had been vacant for more than two years (see "Editor's Column," THE SCIENCE TEACHER, October, 1955, p. 215). Dr. Obourn came to his new position from UNESCO in Paris where for 21 months he was head of the Science Education Department.

Dr. Obourn has been one of the leaders in science education in the United States for thirty years. Most of his teaching career has been devoted to teaching the full range of high school science in the John Burroughs School in Clayton, Missouri, where he was also head of the science department. He is author of several science textbooks and, in collaboration with Heiss and Hoffman, of the popular methods text, *Modern Science Teaching*, published by Macmillan.

Dr. Obourn obtained his B. S. degree from Columbia University, and his M. A. and Ph. D. degrees from New York University. He was an assistant in physics at Columbia and also served a number of years on the staff at NYU. He has taught summers at Duke and Northwestern. A charter member of NSTA and the National Association for Research in Science Teaching, he has served on the NSTA Board of Directors and as secretary-treasurer of NARST for several years.

In 1951, Dr. Obourn went to Thailand as Science Education adviser to the Ministry of Education. He was accompanied by his wife, Honora, who also served as an instructor and lecturer in nursing education, psychology, and public health. Dr. and Mrs. Obourn have established residence at The State House, 2122 Massachusetts Avenue, N. W., Washington 8, D. C.

An Introductory Bibliography on Problem Solving

By JAMES A. RUTLEDGE

Assistant Professor of Secondary Education, University of Nebraska, Lincoln

Blough, Glenn O., and Albert J. Huggett. *Methods and Activities in Elementary-School Science.* New York: The Dryden Press, 1951, Chapter II.

The chapter on "The Objectives in Elementary Science" emphasizes problem-solving as a major objective for elementary-school science.

Boeck, Clarence H., "Teaching Chemistry for Scientific Method and Attitude Development," *Science Education,* 37: 81-84, March, 1953.

A study designed to give some measure of the effectiveness of inductive-deductive chemistry teaching. In the experimental class, the laboratory was used to obtain data on a problem the students had a real desire to solve, whereas in the control classes, laboratory exercises were carried out primarily in accordance with a representative published laboratory manual and were used after thorough discussion to describe principles or illustrate their applications. The results of the study showed that the experimental class did as well or better than control classes in the attainment of the general outcomes of a high school course in chemistry and was significantly superior in knowledge of and ability to use methods of science with an accompanying scientific attitude.

Brownell, William A., "Problem Solving," *The Psychology of Learning.* Forty-First Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1942, Chapter XII.

Problem solving is defined and research in problem solving is discussed. Growth in problem-solving ability and teaching to solve problems are treated; eleven practical suggestions for developing ability in problem solving are presented.

Burnett, R. Will, "Developing Critical Abilities," *Science Teaching in the Elementary School.* New York: Rinehart and Company, Inc., 1953, pp. 79-81.

Discussed briefly are seven aspects of general procedures for tackling problems at the elementary-school level.

Burnett, R. Will, "How Good Teachers Teach Science," *School Science and Mathematics,* 55: 249-270, April, 1955.

Frequently stressed in the discussion of good teaching is the importance of problem-solving approaches. Reasons for its importance are pointed out and substantiated.

Cahoon, G. P. "Using Demonstrations for Providing Pupil Experiences in Thinking," *Science Education,* 30: 196-201, October, 1946.

Five examples of demonstration procedures designed to emphasize scientific thinking and suitable for use with high school students are presented in some detail.

Chase, Stuart. *The Proper Study of Mankind.* New York: Harper and Brothers, 1948.

An attempt is made to explore the possibilities of applying scientific method to problems of human relations. Samplings from the field of social science are presented and various implications and conclusions are discussed. Supplies background rather than specific information for teacher use.

Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

In this Terry Lecture is presented a proposal for an historical approach to science in order to secure an understanding of science and an ability to use its methods. Although aimed at the area of college science, its implications are far-reaching.

Cordell, Anthony, "Answering Children's Questions Through Science Experiences," *School Science and Mathematics,* 49: 395-401, May, 1949.

It is pointed out that children like to come to the science room to work out everyday problems. Examples of the variety of experiences needed to help them find answers to their questions are included in several aspects of elementary science.

Craig, Gerald S. *Science for the Elementary-School Teacher.* Boston: Ginn and Company, 1947. pp. 30-36.

Use of the scientific method in the educational process is treated. The solution of problems by children in science is discussed under the headings of "Defining the Problem to be Studied," "Suggesting a Method of Solving the Problem," and "Arriving at a Solution."

Curtis, Francis D., "A Plea for Inductive Teaching," *The Science Teacher,* 17: 222-224, December, 1950.

The use of the inductive method in laboratory work is stressed. It is pointed out that by using

the inductive method, laboratory work can be made to present a problem and a challenge. The procedures described can provide real problem-solving activity in the laboratory.

Dressel, Paul L., "Critical Thinking—the Goal of Education," *NEA Journal,* 44: 418-420, October, 1955.

The author examines several proposed operating themes or principles for the guidance of teachers; concludes that man's distinctive characteristic is his ability to reason. He contrasts the general concern of teachers for reasoning ability and the paucity of opportunities for the genuine exercise of this ability in many classrooms. He proposes the development of critical thinking as the desired integrating principle or goal of all education.

Heiss, Elwood P., Ellsworth S. Obourn, and Charles W. Hoffman, *Modern Science Teaching.* New York: The Macmillan Company, 1950. pp. 35-37, 48-49, 92-95, 138-155, 164-171, 195-227, 251-271.

The role of problem solving in science learning is presented and elements used in problem solving are outlined and discussed. Certain techniques for developing the skills of problem solving are suggested. Procedures for use in evaluating growth in problem-solving skills are given. In the discussion of evaluation procedures, many devices and techniques for use in evaluating ability in elements of problem solving are presented.

Hurd, Paul DeH., "The Scientific Method as Applied to Personal-Social Problems," *Science Education,* 39: 262-265, October, 1955.

Some of the difficulties involved in applying scientific method to personal-social problems are pointed out. It is held that scientific method has many limitations as a method of approach in the solution of such problems.

Hurley, Beatrice J., "Science Experiences for Nine to Twelve," *Childhood Education,* 26: 300-303, March, 1950.

Ways of helping boys and girls learn how to solve their problems through science are pointed out under the headings "Through Interaction with Their Environment" and "Through Concerns, Interests, and Needs."

Jackson, William N., "Reflective Thinking as a Purpose in High School Science," *The Science Teacher,* 22: 273-276, November, 1955.

Keeslar, Oreon, "The Elements of Scientific Method," *Science Education,* 29: 273-278, December, 1945.

An investigation is reported in which it was sought to derive a comprehensive list of elements of scientific method which would be suitable for instructional purposes in the secondary schools. In the findings are presented an abbreviated list of the elements of scientific method and a simplified and reworded list of these elements for use by high school students.

Laton, Anita Duncan and Samuel Ralph Powers. *New Directions in Science Teaching.* New York: McGraw-Hill Book Company, 1949. Sections II, III.

In the descriptions of new courses developed and new emphases within existing courses, many examples are presented of ways in which new or altered secondary school science courses sought to meet the needs of young people and to help them solve their problems.

Lefler, R. W., "The Teaching of Laboratory Work in High School Physics," *School Science and Mathematics,* 47: 531-538, June, 1947.

The shift in procedures from formal physics to problem solving in the physics classroom is portrayed. Examples of some of the problems which arose and the means used in their solution are given.

Lesser, Milton, "Providing for the Teaching of Some of the Elements of Scientific Method," *Science Teaching Ideas II,* (Abraham Raskin, Editor). Washington: National Science Teachers Association, 1955. pp. 11-12.

A lesson for tenth grade biology specifically designed to promote the use of elements of the scientific method is described.

Miller, David F., and Glenn W. Blaydes. *Methods and Materials for Teaching Biological Sciences.* New York: McGraw-Hill Book Company, 1938, Chapter II.

In the discussion of objectives of teaching in biological subjects, the scientific method of teaching receives considerable attention. The way in which a microcosm developed into a problem-solving situation is described.

Navarra, John G., "Elementary Science as it Relates to the Developmental Problems of Children," *Science Education,* 37: 226-231, October, 1953.

It is indicated that elementary science should help the child to cope with his concerns as they arise in his development. Some specific instances of such concerns are analyzed and some implications for teaching science are stated.

Obourn, Ellsworth S., "Making the Most of Experimental Exercises," *The Science Teacher,* 17: 170-171, November, 1950.

Some suggestions on improving experimental exercises and for utilizing to the maximum the potential values of experimental exercises are made.

(Please continue on page 69.)

Institutes, Conferences, and Fellowship Programs for Science Teachers

An NSTA Staff Report

This summary of opportunities for science teachers for which fellowships or stipends are available is offered as a professional service and lists all opportunities for which we received information by press time for this issue. We as a profession may express our appreciation for these generous offerings from the respective industries, foundations, and institutions by widely announcing these programs. In this listing alone there are opportunities for over 1,000 high school science teachers to participate.

The descriptions give the name of the institution offering the program, dates, name of program and/or special offerings, limitations if any, stipends and sponsor, contact person for additional information, and closing date for applications.

SUMMER PROGRAMS

Alabama College. Six-Weeks Summer Institute for High School Teachers of Science. Fifty $200 stipends provided by the National Science Foundation; $75 for each dependent. *Paul C. Bailey, Department of Biology, Alabama College, Montevallo, Ala.*

American University. Six-Weeks Summer Institute for High School Teachers of the Physical Sciences. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *Keith C. Johnson, Supervisor of Science, District of Columbia Public Schools, Woodrow Wilson High School, Washington, D. C.*

Carnegie Institute of Technology. June 25-August 4. Summer Program for Teachers of Science. The academic program will consist of course work and informal discussions; features a survey of recent developments in the pure and applied sciences through lectures, and industrial and laboratory visitation; emphasis will be placed on teaching methods. $250 fellowships provided by the Westinghouse Educational Foundation for secondary school teachers of science. *Director of Summer Session, Carnegie Institute of Technology, Pittsburgh 13, Pa.*

Case Institute of Technology. June 18-July 27. General Electric Fellowships for Science Teachers. Program designed to enlarge each Fellow's grasp of recent important applications of science and to provide new approaches to basic concepts. Open to secondary school physics teachers in Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, Western Pennsylvania, Tennessee, West Virginia, and Wisconsin. Fifty fellowships available providing tuition, fees, board, lodging, and round-trip transportation from the Fellow's school to Cleveland. *Dr. Elmer C. Hutchisson, Dean of the Faculty, Case Institute of Technology, Cleveland 6, Ohio.* March 16.

Cornell University. July 2-August 11. Shell Merit Fellowship Program. A specially designed program providing seminar type courses, lectures, visits to research and production establishments, informal discussions with outstanding scientists, mathematicians, and educators; opportunities to pursue special projects relating to classroom instruction and pointing toward leadership efforts in the community. Thirty fellowships including a travel allowance, tuition, books, board and lodging, and $500 to help make up for the loss of potential summer earnings are provided by The Shell Companies Foundation, Inc. to science and mathematics teachers and supervisors. Program is closed but generous fellowships for the academic year with emphasis on evaluation are available. *Dr. Philip G. Johnson, Stone Hall, Cornell University, Ithaca, N. Y.*

Future Scientists of America Foundation of the National Science Teachers Association. June 17-30. 1956 West Coast Summer Conference for High School Science Teachers. A "research team" approach concerned with "Science Projects as Stepping Stones to Careers in Science." Conference will be held at Oregon State College, Corvallis, in cooperation with Oregon State College and the Crown Zellerbach Foundation. Open to teachers in grades 7-12 in schools in Washington, Oregon, California, Utah, Idaho, Arizona, and Nevada. Thirty-two $200 fellowships available. *National Science Teachers Association, 1201 Sixteenth Street, N. W., Washington 6, D. C.* April 10.

Harvard University. July 2-August 15. Special Courses for Elementary and Secondary School Teachers. "Recent Developments in Physical Science" and "Teaching Science" for teachers in grades 7-12; eight units of credit may be earned. Twenty $400 fellowships provided by the du Pont Company. *Professor Fletcher Watson, Harvard University Summer School, Weld Hall, Cambridge 38, Mass.*

Howard University. June 18-August 10. The Phelps-Stokes Program for Secondary School Science and Mathematics Teachers. Special courses emphasizing recent developments and new approaches in astronomy, biology, chemistry, geology, mathematics, physics,

and science education. Twenty-four $250 fellowships; enrollment limited to holders of fellowships. *Professor Herman Branson, The Phelps-Stokes Program, Howard University, Washington 1, D. C.* April 15.

Indiana University. Six-Weeks Institute for High School Teachers of Biology. Thirty $300 stipends provided by the National Science Foundation; $75 for each dependent. *Shelby D. Gerking, Department of Zoology, Indiana University, Bloomington, Ind.*

Marshall College. Six-Weeks Institute for High School Teachers of the Physical Sciences. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *Donald C. Martin, Department of Physics, Marshall College, Huntington, W. Va.*

Massachusetts Institute of Technology. July 2-August 10. Summer Fellowships for Teachers of Science. Designed to provide a review of fundamental subject matter in physics, chemistry, and biology; survey of recent scientific developments in these fields and in meteorology, geology, and aeronautical engineering; laboratory visitation. Open to experienced high school and preparatory school teachers of science who hold college degrees or who have had equivalent training and background. Eighty $250 fellowships provided by the Westinghouse Educational Foundation. *Professor Ernest H. Huntress, Director of the Summer Session, Room 7-103, MIT, Cambridge 39, Mass.* April 1.

Montana State College. Five-Weeks Institute for High School and College Teachers. Fifty $250 stipends provided by the National Science Foundation; $65 for each dependent. *L. O. Binder, Jr., Department of Chemistry, Montana State College, Bozeman, Mont.*

Oak Ridge Institute of Nuclear Studies. June 11-July 6, July 9-August 3. Institute for Physics and Chemistry Teachers. Features nuclear science and radioisotopes. Open nation-wide. Limited stipends available; supported by a grant from National Science Foundation. *Dr. Ralph T. Overman, Institute for Nuclear Studies, Oak Ridge, Tenn.*

Ohio State University. June 18-August 31. Summer Program for Teachers of Science. A specially designed program for high school science teachers. Sixteen $325 fellowships provided by the du Pont Company. *John S. Richardson, Department of Education, Ohio State University, Columbus, Ohio.* April 1.

Pennsylvania State University. Six-Weeks Institute for High School Teachers of Science. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *William H. Powers, Arts and Science Extension, Pennsylvania State University, University Park, Pa.*

St. Louis University. June 19-July 27. Institute for Teaching of Chemistry. Program featuring advanced work in chemistry with supporting work in physics, mathematics, and education; also lectures and visits to industrial and research laboratories. Applicants need not be a candidate for a degree. Sixteen $350 fellowships provided by the du Pont Company available to high school and junior college teachers; open nation-wide. *Dr. Theodore A. Ashford, Professor of Chemistry, St. Louis University, St. Louis, Mo.*

Stanford University. June 25-August 21. Shell Merit Fellowship Program. (See description for Cornell University.) Open to science and mathematics teachers and supervisors residing west of the Mississippi. *Dr. Paul DeH. Hurd, School of Education, Stanford University, Stanford, Calif.* May 1. Generous fellowships for the academic year with emphasis on evaluation are available.

Syracuse University. June 24-August 3. General Electric Fellowships for Science Teachers. Program designed to enlarge each Fellow's grasp of recent important applications of science and to provide new approaches to basic concepts. Open to secondary school chemistry and physics teachers in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. Fifty fellowships available providing tuition, fees, board, lodging and round-trip transportation from the Fellow's school to Syracuse. *Committee on General Electric Fellowships, 400 Lyman Hall, Syracuse University, Syracuse 10, N. Y.* March 1.

Teachers College, Columbia University. July 9-August 17. Science Teachers' Workshop. Designed for in-service teachers of physics and chemistry, who are acceptable as graduate students, to explore new content in physics and chemistry and classroom laboratory application of same; program carries six points of graduate credit toward a master's or doctor's degree; workshop is offered by the Department of Science and Science Education of Teachers College and the Departments of Physics and Chemistry of Columbia University. $250 fellowships and tuition provided by the du Pont Company. *Professor Hubert M. Evans, Teachers College, 525 West 120th St., New York 27, N. Y.*

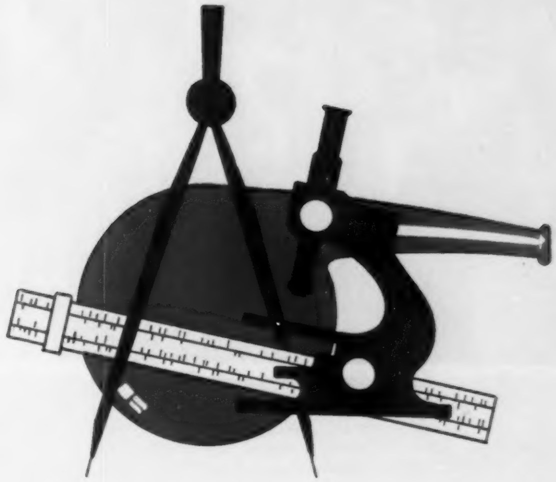
Union College. June 25-August 3. General Electric Fellowships for Science Teachers. Open to experienced secondary school teachers of chemistry and physics in New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, and the District of Columbia. Fifty fellowships available providing tuition, fees, board, lodging, and round-trip transportation from the Fellow's school to Schenectady. *Committee on General Electric Fellowships, Union College, Schenectady 8, N. Y.* March 1.

University of Arkansas. Six-Weeks Summer Institute for High School Teachers of the Natural Sciences. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *L. F. Bailey, Department of Botany, University of Arkansas, Fayetteville, Ark.*

University of Delaware. June 18-July 27. Master's Degree Program for Secondary School Teachers. Program includes two-semester courses in each of three

(Please continue on page 45.)

Science-Related Mathematics Exercises



- A Report to the Science Teaching Profession
- Helping students overcome mathematics hazards to learning and using science
- Prepared by the 1955 West Coast Science Teachers Summer Conference
- Sponsored jointly by San Jose State College, The Crown Zellerbach Foundation, The National Council of Teachers of Mathematics, and The Future Scientists of America Foundation of the National Science Teachers Association

Reported by The Future Scientists of America Foundation
of the National Science Teachers Association
1201 Sixteenth Street, N.W., Washington 6, D. C.

FOURTH ROW—Woodburn, Lane, Fisher, Lillywhite, Coombs, Chinn, Babcock, Bowhay
THIRD ROW—Myers, Kienzle, Wilson, Butterfield, Williams, Williams, Shelton, Moore, Dilley, Blake
SECOND ROW—Donohoe, Porter, Spelbrink, Parker, Stringari, Lisonbee, Scott (G.), Neal, Sipple, Roberts
FRONT ROW—Haas, Scott (W.), Huff, Campbell, Cavins, La Rowe, Rogers, Collins

PHOTO BY DALE KOBY

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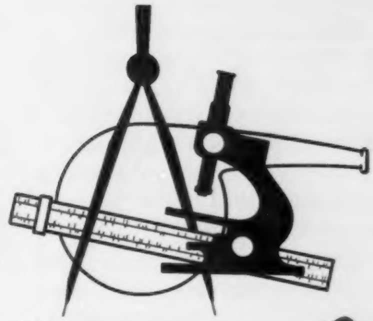
Science-Related Mathematics Exercises



The Hypothesis

New exercises emphasizing the use of mathematics in today's science will help teachers keep more capable students on their way toward scientific, engineering, and technical careers.

The Method

Selected on the basis of open competitive applications, a research team of 34 high school science and mathematics teachers was assembled at San Jose State College. The members brought to the two-week work conference over 2000 hours of academic science course credits and the experiences gained from seeing thousands of boys and girls go through their science and mathematics classes.

They backed up their training and experience with interviews involving more than 50 research scientists and engineers in 33 industrial, government, and university laboratories in the San Jose and San Francisco Bay areas. Additional information was brought to the group by five scientists who served as leaders of evening discussion sessions. By tracing the development and solution of representative problems within their organizations, these 55 scientists showed how abilities in mathematics contribute to the success of new and experienced technical employees.

Upon being asked by the interviewing teams, these men also gave suggestions on how mathematics and science can be better taught in the high school.

The Results

The members of the research team gained a whole new perspective of the opportunities which await young people today in mathematics, science, engineering, and related fields. They saw old scientific principles being used to solve new problems and new principles being explored in the hope they would solve old problems.

As more tangible evidence of their research, the team prepared 15 statements on how they thought more boys and girls can receive the kind of science and mathematics instruction which will cause them to continue toward technical careers. In addition, the team wrote more than 100 new science-related mathematics exercises which reflect what they learnd from their research. Some of the problems simply put familiar skills in a new setting. Some involve new adaptations of old skills and some try to introduce mathematics or science concepts that have not, as yet, appeared in textbooks.

Exercises which combine mathematical skills and science "know-how" gained the greatest amount of attention by the research team. This type of exercise seems to parallel most closely the work of practicing scientists, engineers, and mathematicians.

The 15 recommendations and a selected group of the new exercises comprise the body of this report.

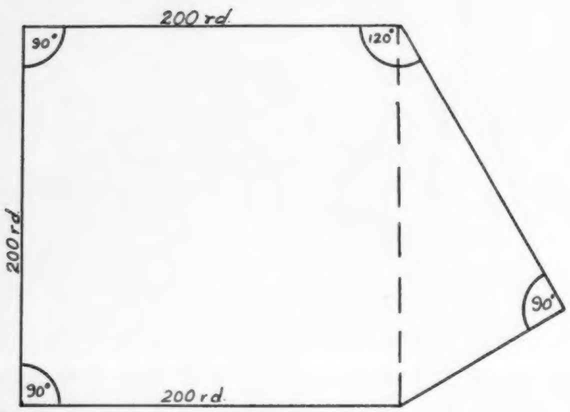


FIGURE 1

1. The California Spray Chemical Company prepares 2-4-D weed killer so that one quart will cover one acre when applied by airplanes. How many gallons of 2-4-D would be needed to spray the field in Figure 1, allowing 10 per cent loss due to wind drift? Compute answer to nearest gallon.

2. To be suitable for use in insecticides, sulfur must be made into very fine dust. This dust will explode with proper oxygen and temperature conditions. To prevent an explosion during the grinding process, the atmosphere is automatically regulated by the addition of carbon dioxide until the total concentration of carbon dioxide is 6 per cent. This carbon dioxide is secured from the stack gases from other plant processes and is scrubbed and chilled. The room where the sulfur is ground is 18 ft. x 15 ft. x 30 ft. What is the volume of carbon dioxide needed to have a total concentration of 6 per cent?

3a. Tin plate is manufactured by steel mills to specifications set up by their customers. One such customer, the Continental Can Company, in turn, makes cans according to the specifications from their customers. A common unit of measurement in tin plate is the "base box." This unit was handed down from the English companies and is 31,360 square inches of plate. It is common to express the weight of tin plate as base box weight. The common base weight range for tin plate is from 70 lb. to 135 lb. A simple calculation of thickness of tin plate may be made by multiplying the specified base weight by eleven and dividing by 100,000. A sheet of tin plate comes from a stock with a base weight of 112. What is the thickness?

3b. A typical customer specification requires a thickness of .0123 in. The company allows a safety factor of 1.5. How thick would the metal actually be that would be used to fill this order?

4. The weight per square inch of a stack of tin plate can be calculated by the following formula (112 sheets to the stack):

$$\frac{\text{(Area) (Base Weight)}}{\text{31,360 sq. in/base wt.}} = \text{Weight of stack per sq. in.}$$

A 30 in. x 50 in. tin plate has a base box weight of 80 lb. What is the weight per square inch of the metal?

5. One machine puts lids on cans at a rate of 1000 cans per minute. (1) How many will it put on per second? (2) How many will it put on in an 8-hour day?

6. Electroplating machines run 5000 linear feet of metal through in one minute. How long will it take to electroplate a strip of metal 1 mile long?

7a. If 450 cans per minute are produced and it is found that a machine is not adjusted properly one-half hour after operations are started, how many cans must be discarded? These cans are sold at $2\frac{1}{2}$¢ each. How much sale value is lost?

7b. This machine runs steadily for an 8-hour day and its rate of spoilage is 0.8 per cent. How many good cans were produced? How many bad cans were produced? What is the sale value of the good cans? How much was lost due to bad cans?

8a. A can is $2\frac{11}{16}$ in. in diameter and $4\frac{13}{16}$ in. long. How many fluid ounces will it hold? (One fluid ounce = 1.80469 cu. in.)

8b. What is the total surface area of the can?

9. What weight of tin is required to plate one base box of 112 lb. steel with a coating 0.00004 in. thick? (Tin weighs 454.27 lb./cu. ft.)

10a. A given Gerbers Baby Foods soup formula requires 630 gal. of puree of 10 per cent concentration. The purchased puree had a concentration of 23 per cent solids. One gallon of the 23 per cent puree is equivalent to how many gallons of the 10 per cent puree?

10b. One gallon of the 10 per cent puree is equivalent to how many gallons of the 23 per cent puree?

11a. A given soup formula calls for 740 gal. of

RECOMMENDATION

High school students should be made aware not only of the vocational opportunities in science but also of the increasing number of opportunities in mathematics. Counselors should recognize that opportunities await students of a wide range of intellectual ability.

ONE

RECOMMENDATION TWO

Science teachers should give more attention to the fact that an individual's ability or lack of ability to use the English language may determine his success or failure in any job. Remember that nothing gets done until the person with the idea explains it clearly to the people who are going to pay for or do the work necessary to put the idea into action.

11.7 per cent concentration tomato puree. The available puree has a concentration of 17.4 per cent solids. One gallon of the 17.4 per cent puree is equivalent to how many gallons of the 11.7 per cent puree?

11b. One gallon of the 11.7 per cent puree is equivalent to how many gallons of the 17.4 per cent puree?

12a. In mixing a batch of soup, the operator makes the mistake of putting in 750 gal. of 19.5 per cent puree rather than the required 9.6 per cent. How many gallons of the 19.5 per cent puree should the operator have added to the batch?

12b. At a cost of $0.73 per gal. for 9.6 per cent puree and $1.47 per gal. for 19.5 per cent puree, how much did the above mistake cost the company?

13a. Apricot pulp and apricot concentrate, classified according to the per cent of solids, are used in the baby food industry. Apricot pulp contains 13 per cent solids and apricot concentrate 24 per cent solids. One day during a 2-hour run, a helper substituted apricot concentrate for apricot pulp without making a formula adjustment. What per cent less of the apricot concentrate should he have used?

13b. If 800 gal. of the apricot pulp should have been used in a 1000-gal. cooker, what per cent of the finished product would be pulp?

14. In each can of food, "head space" is allowed for expansion and contraction. Gerbers allow $\frac{1}{32}$ in. for head space and 8 oz. of fruit pulp to each can. How many cans would be needed to can 4 tons of fruit pulp?

15. Aluminum stock of 0.026 in. thickness is to be rolled into Kaiser Aluminum foil. The foil is actually two sheets rolled together with a total thickness of 0.00035 in. The thickness of one sheet is what per cent of the original stock thickness?

16. Aluminum is alloyed with other metals because the pure metal is difficult to work. When magnesium is added it can easily be machined. A 10-g. alloy sample containing only aluminum and magnesium was found to yield 0.05 g. of MgO (magnesium oxide) in the process of analysis. What per cent of the total sample was magnesium?

17a. The Owens-Illinois Fiberglas Company makes a 2-piece pipe covering, 36 in. long, inside diameter 4 in. wide; and $1\frac{19}{64}$ in. thick. Each piece has a 2-inch extension of waste along each longitudinal seam. The stock or material is 50 ft. long, 38 in. wide and $2\frac{1}{4}$ in. thick. The thickness of the machine material is pressed into the desired thickness of the finished product. How many pipe coverings can be cut from one machine size (Length of covering cut from width of stock)?

17b. How many sq. ft. of waste would there be?

18a. Before a contractor bids on an insulation contract he needs to know the thickness of the insulation necessary so he can figure his cost. The thickness is determined by the conductivity *C*, the Btu's conducted per hr. per sq. ft. per in. thickness per 1°F. difference between the surfaces, the amount of heat that goes through the insulation, and the constant of conductivity *K* for the Btu per hr. per sq. ft. per in. thickness per 1°F difference on the surfaces. Thickness, $T = \frac{K}{C}$. A job must have a minimum conductivity of 0.10. If Fiberglas has a *K* of 0.27, what thickness is necessary?

RECOMMENDATION THREE

High school science and mathematics teachers should be sufficiently familiar with the concepts of statistics, analytical geometry, and calculus to enable them to explain their applications in science-mathematics-related careers. Students should be permitted to take courses from science and mathematics teachers who have been assigned to teach those courses for which they are trained.

18b. If a temperature difference of 10°F. is desired, what thickness is needed?

19a. If the Philadelphia Quartz Company wanted to mix 1000 lb. of sodium silicate of the composition 1 part by weight Na_2O to 2 parts by weight SiO_2 from standards of 1:3.2 and 1:1.6, how much of each standard would be needed? Though this ratio begins as a strict mathematical relationship, there is an actual loss of sodium carbonate (Na_2CO_3) out

RECOMMENDATION FOUR

The ever-increasing use of electronic equipment in science and industry indicates that more time should be devoted to the study of electronics at the high school level.

the stack as a fine powder which introduces a slight error. These ratios are:

Ratio (standard) $Na_2O:SiO_2$	Na_2O (per cent wt)	SiO_2 (per cent wt)
1:3.2	8.9	28.35
1:1.6	14.4	22.8

19b. Procter and Gamble ordered 1000 lb. of sodium silicate of a ratio 1 part Na_2O to 1.8 part SiO_2. Philadelphia Quartz chooses to make this from standard ratios in stock of 1:1.6 and 1:3.2. How would you fill this order?

20. If 10 lb. of a Stauffer Chemical Company herbicide suffices for control of weeds for 1 acre, how much will be needed for your garden plot of 100 ft. x 225 ft.?

21. The chemical fungus control solution used by the Stauffer Chemical Laboratory consists of 100 parts of active chemical to 1,000,000 parts of inert solvent such as water. Write this as a fraction, as a decimal fraction, as parts per million, and as per cent.

22. In a colony of fungus growing in a petri dish, growth takes place only on the outer ring of the colony. Since the circumference is proportional to the diameter, the diameter of the ring is measured as an indication of growth. If the colony in one dish measures ½ in. across the ring and in another, 1½ in. across, how does the growth of the second colony compare with the growth of the first colony?

23a. The crude oil processing capacity of the Tidewater Associated Oil Company's Refinery at Avon, California is 108,000 42-gal. barrels per day. What would be the dimensions of a single cylindrical tank large enough to hold this entire amount? (Several answers are acceptable depending upon which radius and height are used by the students.) Make a scale drawing of the tank.

23b. What uniform size would be necessary if 9 cylindrical tanks of the same dimensions were utilized to store the 108,000 barrels? Make a scale drawing of the tank.

24a. The inflow of crude oil from the oil field pipeline at the Tidewater Associated Refinery is at the rate of 3 miles per hr. in 9 in. pipe. Calculate the time required to fill a tank of 50 ft. radius and 40 ft. height.

24b. Determine the volume of this amount of crude oil in barrels. (Assume 42 gal./bbl.; 231 in^3 per gal.)

25a. Triangular graphs may be used to show the relationships between three different things. Greases quite often have three ingredients. If an oil company wishes to fill a government order for greases, there will be three things to mix proportionally. A single point on the graph will define any grease. A line on the graph may define a family of greases having similar properties. The essential characteristics of a triangular graph are shown in the following paragraph.

In an equilateral triangle, the sum of the perpendiculars to the sides from a point within the triangle is equal to an altitude. Given: $\triangle$ ABC, P, a point within; h_1, h_2, and h_3 are $\perp$ to AB, BC, and AC respectively. Prove: $h_2 + h_1 + h_3 = CD$.

PHOTO BY DALE KOBY

Dr. Luis de Alcuaz reviews his solutions to several quality production control problems in the Oakland, California, plant of Gerber's Baby Foods.

25b. Scale lines and scale figures are clearly shown, for instance, the point "x" indicates a value for each variable; for component "A" 20 per cent, for component "B" 30 per cent, for component "C" 50 per cent. Thus any grease may be recorded as a point on the graph. If three components of a grease are oil, soap and additive, from the values below plot them on a triangular graph.

Grease	Oil (per cent)	Soap (per cent)	Additive (per cent)
A	80	15	5
B	60	20	?
C	?	35	10
D	80	5	?

25c. A family of greases is defined by the two greases e, and f.

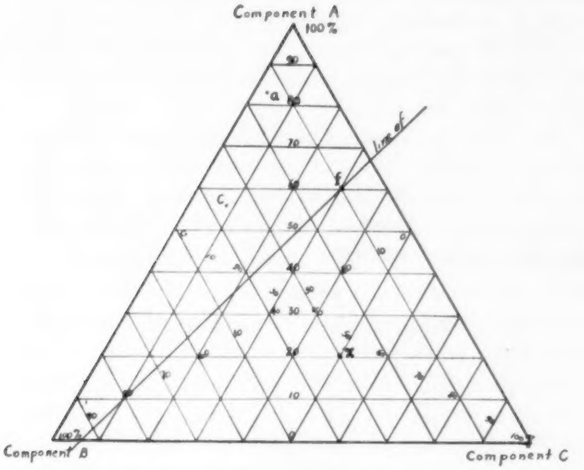


FIGURE 2

	Oil	Soap	Additive
e	10	80	10
f	60	10	30

Find at least three more greases having similar properties.

26. Study of the chart below will show the following facts.

	Steak	Potatoes	Minimum requirements
(A) Carbohydrates	1	3	8
(B) Vitamins	3	4	19
(C) Minerals	3	1	7
Cost	50	25	34

(1) An adequate diet will contain a minimum of 8 units carbohydrates, 19 units vitamins, and 7 units minerals.

(2) One serving of steak will provide 1 unit carbohydrates, 3 units vitamins, and 3 units minerals.

(3) One serving of potatoes will provide 3 units carbohydrates, 4 units vitamins, and 1 unit of minerals.

How many units of steak diet will provide at least a minimum diet? How many units of potato will provide at least a minimum diet? Can we set up a mathematical representation of the above conditions? Can we set up any mathematical representation of cost?

If study of the above relationships indicates no simple solution, attempt a graphical solution. Graph the three functions as equalities of any point so the right of the boundary QSRP will exceed the requirements. By graphing $50x + 25y = $ a minimum as a slope, can you go ahead to answer the steak and potato questions above.

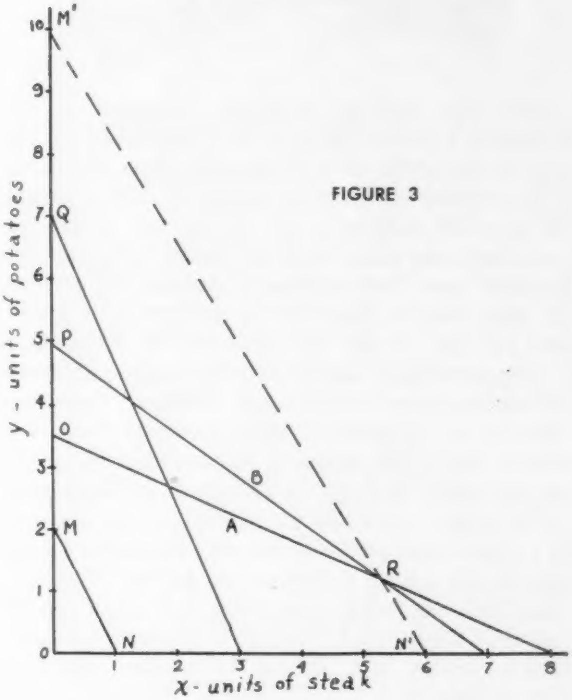


FIGURE 3

27a. One problem faced by the California Research Corporation was the development of a grease for use in army air craft which would have a working texture at extremes of temperature such as —65°F. to 200°F. The apparent viscosity is affected by soap content, oil viscosity, and worked penetration. As a means of reducing the time involved in determining the apparent viscosity of greases, this nomograph was developed for an oil viscosity of 100°F. Determine the apparent viscosity if the grease contains 10.6 per cent soap, has

RECOMMENDATION

In non-school situations, the experiment or solution that did not produce the anticipated result occurs much more often than does the successful solution. Such circumstances, however, seldom condemn the experimentor as having failed or as being incompetent. He is encouraged to study his failures and incorporate what he learns in a new attack on his problem. High school mathematics and science teachers should strive to produce this same atmosphere in their classrooms.

FIVE

a viscosity at 100° F. of 73.0 and a worked penetration of 281.

27b. What is the soap content of a grease with an apparent viscosity of 13,300, a viscosity of 73 and a worked penetration of 295?

RECOMMENDATION SIX

Mathematics and science teachers should capitalize upon each opportunity to let their students see how all branches of science are inextricably interwoven in naturally occurring phenomena and practical problem situations. This must be done, however, in the existing high school mathematics and science courses. It is becoming increasingly important that the science-mathematics experiences provided for boys and girls at each grade level be so planned as to provide a continuing enrichment of prior experiences.

28a. The building of water softeners by the Chemical Process Company is accomplished by the organic synthesis of sodium-polystyrene sulfonate.

The amount of material (labeled C-20) necessary to maintain sufficient soft water for household, manufacturing plant or a laboratory is largely dependent upon the following conditions: the amount of water needed, hardness of the source of water, and the size of the ion-exchange unit installed.

Regeneration of the ion-exchange resin is achieved by washing with a sodium salt solution. For every calcium or magnesium atom removed from the source water, two atoms of sodium must be added to regenerate the C-20. A number of problems arise in the manufacture and use of C-20. This material is a high capacity base-exchange resin which means that it has a high exchange rate for removing calcium and magnesium from water. A graph can be prepared from the following data which indicates time-water use intervals for determining regeneration periods for a 500-gallon unit.

No of Days	1	2	3	4	5	6	7	8	9	10	20
Gal/day	500	250	166	125	100	83	71	62.5	55.5	50	25

Prepare a graph and extend for more or less usage of water.

28b. If 100 gals. of water were processed per day, when would regeneration be necessary?

29a. The following data from the Food Machinery and Chemical Corporation were obtained by inserting a thermocouple into a 603 x 700 can of cut green beans filled with 2 per cent brine during an experimental processing period and recording the resulting temperature relative to time. Plot a heating and cooling curve from these data. How long does it take for the contents of the can to reach the highest or maximum temperature?

29b. Would you expect the maximum temperature inside the can to be the same as the temperature of the cooker?

30. Does the temperature increase at a constant rate? Explain. Why is the curve flat at the beginning? During the cooling process, does the temperature decrease as rapidly as it increases during the heating process?

TABLE I

Time (Min)	Temp (°F)	Time	Temp	Time	Temp
0	60	13	225	29	247
1	60	14	230.5		
2	59	15	234.5	30.5	247
3	60	16	238.25	31	247
4	70	17	240	32	246.75
5	85	18	241.5	33	233.5
6	108	19	243.25	34	217.5
7	133	20	243.75	35	203
8	156	21	244.75	36	189
9	175	22	245.25		
10	192	23	245.75		
11	207	25	246.25		
12	217.5	27	246.75		

31a. Table II gives experimental data on the killing of spores in a 603 x 700 can of cut green beans with a 2 percent brine. The data give the time necessary at various temperatures to destroy all but one of the 10,000 spores placed in the can. Plot the thermal death time curve for these data.

TABLE II

Time (Min)	Temp (°F)	Time	Temp	Time	Temp
250	207	3.62	240	1.72	245.75
62.5	217.5	2.98	241.5	1.61	246.25
24.3	225	2.48	243.25	1.51	246.75
12.0	230.5	2.22	243.75	1.46	247
7.33	234.5	1.93	244.75		
4.57	238.25	1.83	245.25		

How many minutes will it take to kill all but one spore if the can is cooked at 220° F.?

31b. Suppose you want to kill all but one spore in 10 minutes. At what temperature must you cook the can and its contents?

32. In actual practice the temperature of the can being processed follows the heating and cooling curves and is therefore constantly changing. The thermal death curve determines death time at a constant temperature. These two curves must therefore be combined into one, a lethality curve, before the time and temperature for cooking food

may be determined. This curve is plotted as follows. In Table II, take the reciprocal of each time in minutes, and make a new table, Table III, as follows:

Temp. °F	Lethal Rate, Deaths/Min.
207	.004
217.5	.016
225	
230.5	
234.5	

This gives the lethal rate in deaths/minute for a given temperature. Take the temperature for each lethal rate in table III and by referring to your first graph determine the corresponding time. Plot this time vs the lethal rate to obtain the lethal rate curve.

33a. In the old milk sterilization process the temperature had to be held at 245-250°F. for 10-15 minutes. The flavor was damaged so that Foremost Dairies looked toward a better process.

It is well known that the time for milk sterilization varies inversely as the holding temperature. It has also been established that the destruction of bacteria varies directly as the temperature. It was further discovered that upon selecting a particular sterilization value (F_0) that the time needed for killing bacteria was decreased to 1/10 or 10 minutes for each 18 degrees rise in temperature. It was also observed that if the holding temperature was increased by 18°F. (while the holding time remained constant) that the sterilization value (F_0) increased to 10 minutes.

Complete the following table:

Fahrenheit Temperature	Time Minutes	F_0 Sterilization Value
250	1	1
268	1	10
286	A	10
B	1/100	10
322	C	10

RECOMMENDATION

Government, industrial, and university research organizations should be encouraged to provide reports on new products or information on basic theories at such a level as to be suitable for use by high school students. The teaching profession should cooperate in the production and distribution of such materials.

SEVEN

33b. Plot the sterilization curve when F_0 equals 10, using time (in seconds) as the ordinate and temperature (in degrees Fahrenheit) as the abscissa.

33c. Plot the same values on semi-log paper.

34. A technician in the electrical testing laboratory of Hewlett-Packard is asked to determine the characteristics of a 6J5 vacuum tube. He runs 4 tests on the tube and obtains the following data.

RECOMMENDATION

Students of high ability should be encouraged to exploit the potential of their ability to the greatest extent possible. In addition, appropriate science and mathematics training should be available to all students and taught as subjects that are practical, dynamic, and of value in modern society.

EIGHT

TUBE CHARACTERISTICS DATA OF A 6J5

TEST #1 Zero Grid Volts		TEST #2 4 Grid Volts	
Pl. Volt. (volts)	Pl. Cur. (ma)	Pl. Volt. (volts)	Pl. Cur. (ma)
0	0	75	.3
25	1.8	100	1.6
50	4.4	125	3.7
75	7.3	150	6.5
100	10.7	175	9.6
125	14.5	200	13.2

TEST #3 8 Grid Volts		TEST #4 12 Grid Volts	
Pl. Volt.	Pl. Cur.	Pl. Volt.	Pl. Cur.
150	.4	200	0
175	1.6	225	.6
200	3.3	250	1.6
225	5.8	275	3.3
250	8.8	300	5.5
		325	8.2

What value of plate voltage is required for a plate current of 10 milliamperes (ma) on Test #1? On Test #2?

35. With a plate voltage of 240 volts, what plate current will flow on Test #3? On Test #4?

36a. One of the basic problems of Jenning's Radio in designing switches for electrical circuits is the fact that electricity will arc over the gap before the switch is completely opened or closed. This arcing lowers the life expectancy of the switch. In order to shorten the distance and also decrease the

Five teachers trace the development of an engineering problem in the Marchant Calculators, Incorporated plant.

arcing tendency, a switch is used that operates in a high vacuum. (3.5 mm x 10^{-8})

The following data were obtained experimentally. Plot both graphs on the same coordinate axis.

DRY AIR		HIGH VACUUM	
Gap in thousandths of an inch	Voltage (kilovolts)	gap	voltage
0	0	0	0
50	5	10	36
100	10	20	54
150	12.5	30	69
200	15	40	81
250	17	50	94
300	18.7	60	104
350	19.5		

If a .050 in. gap in dry air carries 5 KV (kilovolts) and 94 KV in vacuum, what percent increase in efficiency is obtained?

36b. If an .050 in. gap in dry air carries 5 KV and a .150 in. gap carries 12.5 KV why doesn't a .300 in. gap carry 25 KV?

36c. The motion of one pole of a vacuum switch is controlled externally through a metallic bellows. The life of the bellows is based on the number of movements and the distance moved. Thus if the number of movements is fixed by government specifications the only variable is the gap. How can the gap be reduced and still increase the KV rating?

36d. If the vacuum obtained is only 50 percent of the vacuum in the graph would all the KV ratings be one half reduced?

RECOMMENDATION NINE

Students should be encouraged to take part in assemblies, displays, science fairs, and other activities that stimulate interest in mathematics and science.

36e. What gap setting in vacuum would you use for 120KV: 140KV?

37a. These problems represent semi-log graphing as used in research for industry by The National Canners Association.

Inoculated samples of strained peas were subjected to a temperature of 240° F. and the survivors counted in six cultures after varying times. The following data were obtained:

Time (minutes)	Ave. Survivors per culture
0	10,000
10	90
14	12
18	2
22	0.34

Plot these data on semi-log paper.

What type curve is obtained? Plot this curve on regular graph paper. What is the advantage of semi-log paper?

37b. The following equation is applicable to this curve to find the death rate value D.

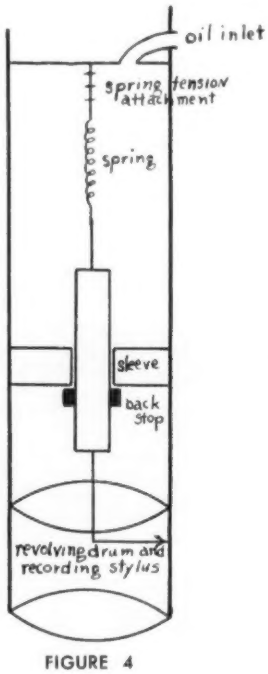


FIGURE 4

$$D = \frac{U}{\log_a - \log_b}$$ U is the time difference between t_2 and t_1.

What is the death rate after the first 18 minutes of heating?

Can you derive the above equation?

What is D in relation to the curve?

38. A pertinent problem to the oil industry is that of keeping the pressure in an oil well from varying in a discontinuous manner. One method used to accomplish this is a recording well pressure guage. A sketch of this instrument is shown in the accompanying diagram.

The formula for the pressure as measured by this device is:

$$P = S_t\ (C_t + d)$$

where

P = pressure of oil in psi

S_t = spring constant in psi/inch deflection

C_t = a cocking factor derived during calibration

d = recorder reading in inches.

If $S_t = 502.2843 - 0.094216\ t$

$C_t = 2.3900$

$d = 2.4800$

$t = 86°$ F.

Calculate the value of the oil pressure in a well under these conditions.

39. In the manufacture of 2–4–D, 2,4, dichlorophenoloxyacetic acid is esterfied with isopropyl alcohol. How many grams of isopropyl–2,4, dichlorophenoloxyacetate will be formed in the reaction from each kilogram of the acid? This reaction gives an 88 per cent yield of the ester.

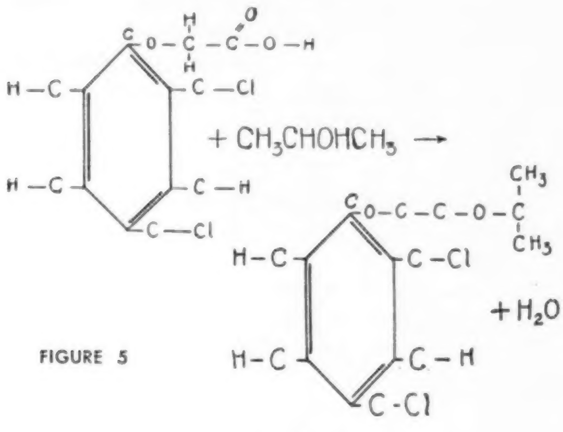


FIGURE 5

isopropyl alcohol

(acid) 2,4, dichlorophenoloxyacetic acid

(ester) Isopropyl 2,4, dichlorophenoloxyacetate

RECOMMENDATION TEN

Industry should be encouraged to support more educational research.

40. Another California Spray Chemical Company product, orthocide, is a recently developed fungicide containing captan, $C_9H_8Cl_3NO_2S$, or N-trichloromethylmercato-4-cyclohexene-1,2 dicarbonimide, a chemical derived from petroleum. Tests by experiment stations found it to be non-toxic to plants and very low in mammalian toxicity.

Results of a corn seed germination test at Purdue University:

Treatment oz./bu.	0.5	1.0	2.0	3.0
Orthocide 75	92.7	92.7	93.7	93.5
Treatment "B"	81.2	93.2	91.2	92.0
Treatment "C"	89.5	90.7	91.7	94.2

Select various types of seed treatment materials and for each of these prepare a covered dish with moist paper towel lining and in this place 100 grains of corn to be tested. At the end of 5 days, count the number of germinated seeds in each dish and tabulate results as above.

RECOMMENDATION ELEVEN

Greater emphasis should be placed on the teaching of approximations as a means of exploring and checking possible solutions to problems as is done continuously in industry.

41. Solubility of captan.

Solvent	Grams captan/100 ml solvent –70°F
Chloroform	8.0
Ethyl acetate	4.5
Acetone	3.0
Benzene	2.0
Methyl alcohol	0.3
Carbon tetrachloride	0.2
Water	insoluble
Ethyl ether	insoluble

Weigh 10 g. of captan and of each of the materials desired to test and place each on a piece of paper. From each sample take a small quantity at a time and add to a flask containing 100 ml of a selected solvent and stir well. When some of the material fails to dissolve, weigh the remaining part of the original 10 g. and tabulate the results as above. *(Note: The analytical laboratory method is more complex and more accurate in results.)*

42a. Nine moles of styrene (C_8H_8) will polymerize with with one mole of divinylbenzene ($C_{10}H_{10}$) to form a resin, polystyrene ($X(C_{82})$ which is used in the production of the ion-exchange material. If we wish to make 100 kilograms of the resin, what weight of styrene is needed? What weight of

divinylbenzene is needed. (Assume 100 per cent reaction.)

42b. By analysis the composition of this resin is found to be 92.5 per cent carbon and 7.5 per cent hydrogen. What is the simplest empirical formula?

43. The composition of sodium alkylarylsulfonate, the activated exchange ion resin, is found by analysis to be 51.4 per cent carbon, 4.4 per cent H, 13.7 per cent S, 20.6 per cent oxygen and 9.8 per cent Na. Find the simplest empirical formula.

Element	%	Mol. wt.	% Mol. wt.	Ratio.
C	51.4	12	42.8	10
H	4.4	1	44	10
S	13.7	32	4.3	1
Na	9.8	23	4.4	1
O	20.6	16	12.8	3

44a. Beverage cans are coated inside with a plastic base varnish to protect the quality of the beverage. To test this coating an electrical set-up is made as follows:

A liquid electrolyte is poured into the can and the anode point contacts are scratched into the bottom of the can. A carbon cathode is dipped into the electrolyte. The small holes in the plastic varnish or foreign inclusions in the tin plate will cause a reading of microamps. A reading of less than 185 microamps is tolerated by the manufacturer. If the reading is greater than 185 and following test samples get progressively larger, production is stopped until correction has been made.

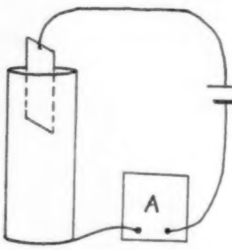


FIGURE 6

A constant 2.75 DC voltage is applied to the test sample. 1500 microamps are measured. What is the resistance involved?

44b. Continental Can Company tolerates nothing greater than 185 microamps for certain kinds of cans, while the consumer tolerates readings as great as 1500 microamps. What is the safety factor involved?

45a. If a disc of metal 3½ in. in diameter is needed to make one can lid, how many lids can be made from a strip of metal 48 in. wide and 2000 ft. long? (There will be two obvious arrangements of discs on the material.)

45b. What is the savings effected by the most economical arrangement? Express the answer in terms of percentage increase in production.

45c. What would be the weight of the scrap material for each arrangement if the base weight was 112 lb. for 31,360 sq. in.?

46. Dalmo Victor Company is using a motor of 1800 rpm to drive a rotating radar antenna. A 12 tooth gear "A" is attached to the motor shaft and drives a 36 tooth gear "C". A 12 tooth gear "B", concentric with "B" attached solidly to it, drives a 36 tooth gear "D" to which 10 tooth gear "E" is attached. The gear train system continues to gear "J" which is the antenna shaft.

How many teeth must antenna shaft gear "J" have if the shaft is to rotate at 5 rpm?

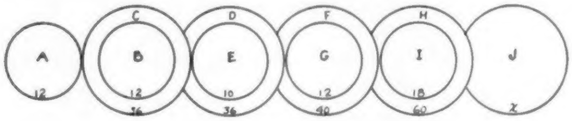


FIGURE 7

47. In order to keep the results of radar screen readings as nearly accurate as possible it is necessary that its swing through a given arc be at a constant rate. In order to stop the motion at either end of the arc it was necessary to install a bumper spring sufficient to take up the energy of motion without providing any throwback. Explain the following method used by Dalmo Victor Company, in solving this problem.

Given:

Thickness of material used $h_1 = .065$ $h_2 = .071$
Width " " " $b_1 = .180$ $b_2 = .185$
Length " " " $= 1.535$
Elasticity factor for material used $E = 3 \times 10+7$
Max. deflection for given situation $= .059$
Endurance limit for material used 108,000 Psi

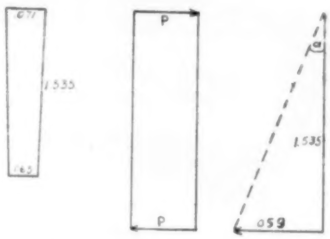
Formulas:

Moment of Inertia $I_1 = \dfrac{b_1\, h_1^3}{12}$ and $I_2 = \dfrac{b_2\, h_2^3}{12}$

Force $P = \dfrac{3\, EI_2}{}$

Max. Stress $F = \dfrac{P\,(\tan)}{I_1}$

FIGURE 8



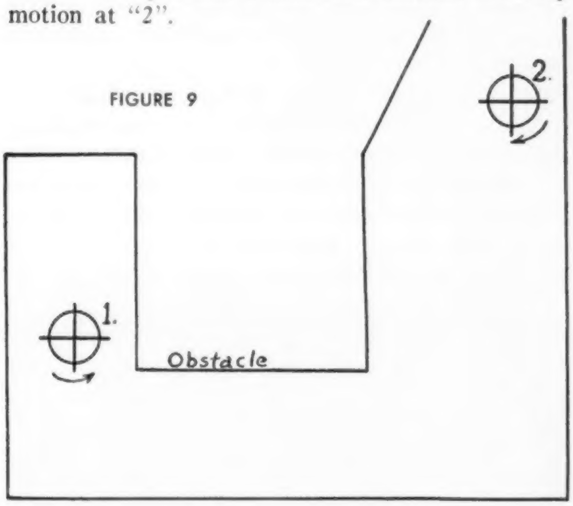
48. A radar detector devised by Dalmo Victor Company, ascertains the altitude, course, and aver-

age velocity of a plane. In case of defense this information is valuable in calculating the fixing of rocket missiles to hit attacking planes. Assume the missile is to be fired straight up. After being fired it accelerates at 50 ft. per sec.[2] The target plane travels on a course toward launcher at velocity of 300 miles per hour at an altitude of 22,500 ft. What would be horizontal distance of plane at time missile is fired to insure a hit? How long before hit would rocket be launched?

49. Designers in the Friden Calculating Machine Company often encounter problems in which motion of one sort must be transferred to a remote part of a machine. The following exercise illustrates such problems.

By cutting various sizes and shapes of bell cranks and connecting rods from cardboard, using dowel rods for shafts, and wrapping cord for belts, show how vertical motion at button "1" can be transferred to rotary motion at "2" in the accompanying figure. Measure the length of each part, transfer your solution to a system of triangles, and show how a measured amount of vertical motion on button "1" can produce a calculated amount of rotary motion at "2".

FIGURE 9



50a. Calculate external resistance to be added to a D.C. voltometer to increase its capacity by 2 times. Then calibrate the scale for the new range. Assume that the meter has a full scale reading of 5 volts with a total internal resistance of 300 ohms normally.

50b. Find external resistance needed to make the range 5 times normal and give new readings on scale.

51a. Find the percentage yield of monosodium glutamate (MSG), if the raw material used by the Ac'cent factory of the International Mineral and Chemical Corporation, Steffen filtrate, will give 11 tons of MSG per 180 tons of raw filtrate.

RECOMMENDATION TWELVE

Students interested in mathematics and science should be stimulated by increasing the amount of scholarship and loan money available for capable students who need help.

51b. How many pounds of NaOH (sodium hydroxide) are needed to neutralize completely one ton of glutamic acid?

52. A qualitative taste test for the effectiveness of "Ac'cent" monosodium glutamate provides this problem.

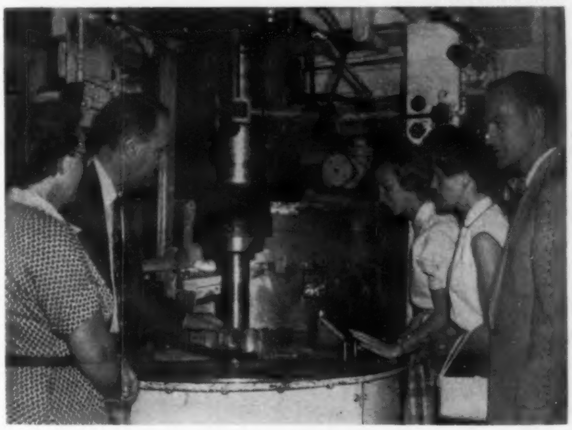
To 100 m.l. of distilled water add two drops oil of wintergreen. Taste. Add water until the taste is no longer detectable. Add a pinch MSG (monosodium glutamate) and taste again. The wintergreen taste should return. What is the minimum concentration of MSG that will restore the wintergreen taste?

53. To conserve water used for cooling purposes in the International Minerals and Chemical Corporation plant, the water is passed through a cooling unit and reused. The temperature of the water entering this particular cooling unit is 158° F. The temperature of the water leaving the cooling unit is 82° F. The plant requirements are 1000 gal. of water per minute. Calculate the number of calories of heat that must be removed by the cooler per minute in order to reduce the temperatures from 158° F. to 82° F.

54. Melt two large test tubes of acetamide to the same temperature and place into each a Centigrade thermometer. Suspend one tube in a vacuum

The centrifuging of monosodium glutamate is explained to four Nevada teachers by E. M. Card, Jr. in the Ac'cent plant of International Minerals and Chemical Corporation.

PHOTO BY DALE KOBY



in such a manner that the thermometer can be read. Leave the other tube at the room pressure. On a graph record the temperature of each at one half minute intervals. Which has a greater cooling rate? Which then would seem to have the greater cooling problem, a switch in vacuum or a switch in air?

55a. In the manufacture of vacuum type high voltage condensors by Jennings Radio Company the gap between the two sets of concentric circular plates may be as much as .040 in. or as small as .005 in. What is the ratio of these sizes? If the thickness of the condensor plates is .015 in. what are the ratios of the size of the plates to the two openings?

Jack Brummett shows four Washington teachers how he tracked down a quality control problem in the Continental Can plant at San Jose.

Glass lathes used in the manufacture of high vacuum, high voltage condensors turn approximately 100 rpm. What would be a formula to find the surface speed of a glass tube in ft./minute if the diameter and the rpm. were known?

56. One of the problems of box manufacturing is to make boxes which, when stacked, the top one will not slide off in moving. The coefficient of friction is the factor that can be varied to meet the situation. The common method is to measure the pull c a spring balance and calculate the coefficient from the following equation:

$$K = \frac{\text{Force of Friction}}{\text{Weight}}$$

A simple method of determination can be done by tipping the boxes and measuring the angle at which the top box begins to slide. Find K if the angle is 30°. By use of a vector diagram prove the answer above. Secure two oblong boxes and test the validity of the physical principles in its application to the project.

Would the relative centers of gravity have any effect on the sliding?

57. The Owens-Corning Fibreglas Company has developed a method of determining average glass fiber diameter very quickly. A standard weight of the insulating material is compressed into a standard volume. Then compressed air is forced through the sample and the pressure drop is measured. For a given weight of material occupying a given volume, the pressure drop varies inversely as the average diameter of fiber. That is, the pressure drop is greater when the individual fibers are smaller in diameter. This ingenious method of measurement makes use of the relation between the volume and surface of a cylinder.

Wooden dowel pins, all of the same length, say 6 in. long; 1 of 1 in. diameter; 4 of ½ in. diameter and 16 of ¼ in. diameter. Sort the dowel pins into three groups according to their diameters. Measure the pins and compute the volume of material in each group. Then compute the total lateral surface in each group.

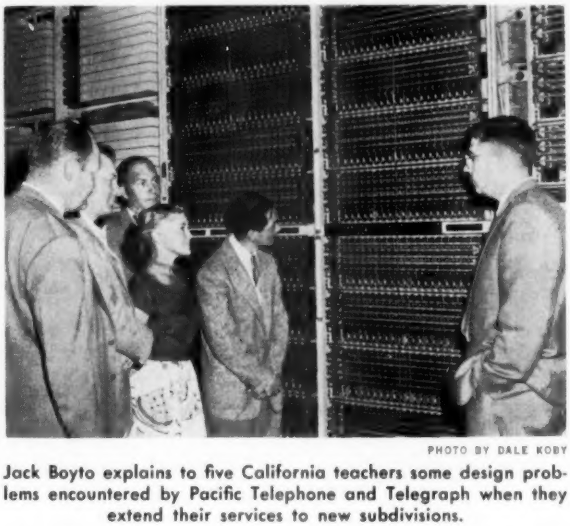


PHOTO BY DALE KOBY

Jack Boyto explains to five California teachers some design problems encountered by Pacific Telephone and Telegraph when they extend their services to new subdivisions.

58. A dead-end pole supports a cable that pulls with a force of 3000 pounds at 20 feet above the

RECOMMENDATION

Science and mathematics students should be encouraged to take part in courses and activities which promise to develop their social proficiency and emotional stability.

THIRTEEN

RECOMMENDATION FOURTEEN

Ingenuity and creative ability can be developed. In young people the spark of ingenuity first shows up as curiosity. Teachers must nourish this curiosity but not offer answers on silver platters because if they do, their students will get the impression that answers always come easily. Sooner or later, students have to learn that answers don't come easily.

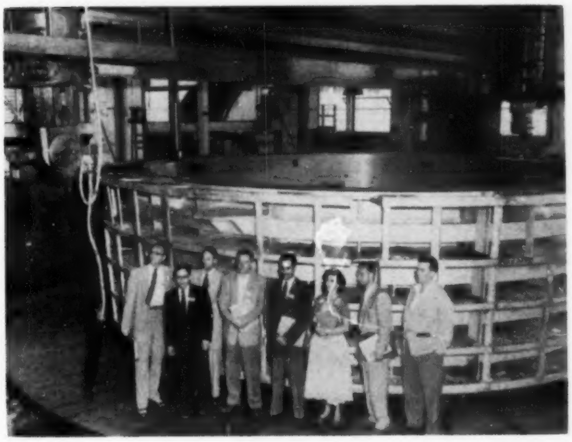
ground. What tension is on the guy wire that supports the pole if the wire is anchored on the ground 18 feet from the pole?

59. Start several bacteria colonies on a standard agar culture media. Pick a colony whose margin appears circular. Measure its diameter every day for several days and determine the average growth of the colony. Graph the results—time against average growth.

60. Dissolve corn syrup in water so that you have different known solutions such as 1 part corn syrup to 1 part water, etc. Put these solutions in graduated cylinders so all stand at the same height. With a stopwatch, determine the time it takes a ball bearing of the same size to reach the bottom of the cylinder (a viscosity test).

Put your findings into a graph using the solution ratio as the ordinate and time as the abscissa.

What is the equation for the curve?



A group of participants is shown where production and control problems arise in Westinghouse's Sunnyvale plant.

61. Prepare petri dish cultures of spore producing bacteria. Each day for 5 days measure the size of each colony. Do the following:

a. Measure the colony in metric measurement.
b. Determine the area of the colony in sq. cm.
c. Measure the diameter of the colony in inches.
d. Determine the area of the colony in sq. in.
e. Determine the per cent of growth and rate each day.
f. Prepare a graph depicting the growth each day.
g. Suggest methods that might be used as short cuts for determining the increase in area and the per cent.

62. The Varian Associates' Magnetometer has a glass quart bottle filled with water for a core. How many molecules would be in one quart of water?

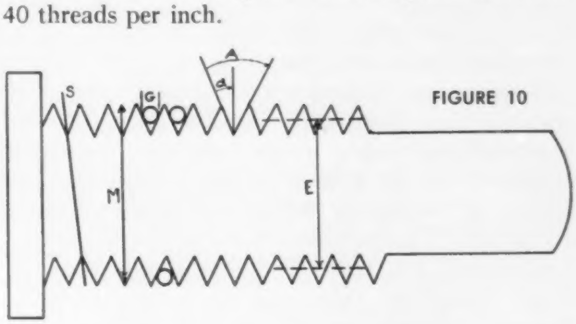
63a. One of the problems encountered in the tool testing section of Westinghouse Electric Company of Sunnyvale, California, is that of determining the pitch diameter of machine bolts. A direct measure of this value can be made, but only with a special micrometer which is very expensive. In lieu of such costly equipment, Westinghouse engineers use a method known as the "three wire method" which involves the placement of wires between the threads. Then they take the convenient measurements indicated in the diagram below and calculate the pitch diameter by means of the formula:

$$E = \frac{M + \cot A}{2N} - G\left(1 + \csc a + \frac{\tan^2 S \cos a \cot a}{2}\right)$$

Where E = pitch diameter
M = diameter as measured over the wires
A = angle between the threads
a = ½ angle between the threads
N = number of threads per inch
G = diameter of wires
S = helix angle

Calculate E when $M = 0.13195$ in., $A = 60°$, $a = 30°$, $S = 4° 45'$, $G = 0.01443$, and there are 40 threads per inch.

FIGURE 10



63b. Calculate E when $M = 0.57641$ in., $A = 60°$, $a = 30°$, $S = 3° 7'$, $G = 0.04441$, and there are 13 threads per inch.

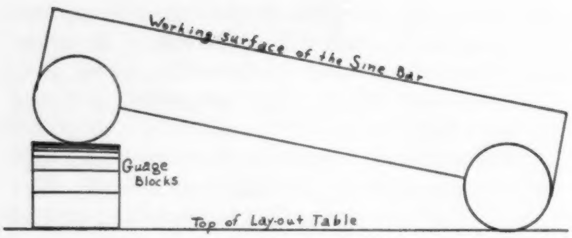


FIGURE 11

64a. The device used to set up any angle in layout work in a machine shop is called the sine bar. This is an accurately finished piece of metal with two rollers at the ends as shown. The distance between the centers of the rollers is 5 in. in the case of a 5 in. sine bar and 10 in. in the case of a 10 in. sine bar.

If a 5 in. sine bar were placed on an incline, how far would it be between the points of contact of the rollers with the incline?

64b. Given a 5 in. sine bar, what height of gauge blocks would you require to set up an angle of 10° 40′? If you wanted to set up the same angle (10° 40′) using a 10 in. sine bar instead of a 5 in. sine bar, what height of gauge blocks would you use?

Administration

TO PROVIDE A WIDER BASE from which plans could originate, be evaluated, and put into action, a Development Committee was appointed by the NSTA Executive Secretary. The committee included: Mr. M. H. Ahrendt, National Council of Teachers of Mathematics (NEA); Dr. Kenneth Brown, U. S. Office of Education; Mr. John Coleman, National Research Council; Dr. Charles B. Hunt, American Geological Institute; Dr. B. R. Stanerson, American Chemical Society.

To insure professional status and full coordination with the total education profession, all plans were submitted for review by an Advisory Committee composed of: Dr. Paul E. Elicker, National Association of Secondary School Principals (NEA); Dr. Walter S. Lapp, Overbrook High School, Philadelphia, Pa.; Dr. Harry F. Lewis, The Institute of Paper Chemistry, Appleton, Wis.; Dr. John R. Mayor, University of Wisconsin, Madison; Dr. Robert Stollberg, San Francisco State College, Calif.; Mrs. Marie S. Wilcox, Thomas Carr Howe High School, Indianapolis, Ind.

To predict the kinds of data to be obtained from interviews with scientists in their laboratories, four trial interviews were arranged. The scientists and their projects were: Dr. Hazel M. Fletcher, U.S. Department of Agriculture, "Elastic Recovery in Knitted Fabrics and Their Dimensional Change in Laundering"; Barry W. Mulligan, Dr. W. J. Youden, Dr. A. T. McPherson, National Bureau of Standards, "The Development of a Method for Determining Concentration of Alkalies in Refractory Materials"; Dr. John B. Wachtman, National Bureau of Standards, "Structural Properties of Monocrystalline Materials"; Dr. H. R. Reed, University of Maryland, "Lobe Modulation as a Source of Radio Interference for High Speed Aircraft".

Half-day or full-day interviews for teams of from four to sixteen teachers were provided by the following organizations: California Research Corporation, California Spray-Chemical Corporation, Chemical Process Company, Continental Can Company, Cutter Laboratories, Dalmo Victor Company, Fibreboard Products, Food Machinery and Chemical Corporation, Foremost Dairies, Friden Calculating Machine Company, Gerber Products Company, Hewlett-Packard Company, Illumitronic Engineering Company, International Business Machines Corporation, International Minerals & Chemical Corporation, Jennings Radio, Kaiser Aluminum & Chemical Corporation, Marchant Calculators, National Advisory Committee for Aeronautics, National Canners Association, Owens-Corning Fibreglas Corporation, Pacific Telephone & Telegraph Company, Philadelphia Quartz Company, Shell Development Company, Stanford Research Institute, Stauffer Chemical Company, Tide Water Associated Oil Company, University of California Radiation Laboratory, Varian Associates, Western Regional Research Branch of the U.S. Department of Agriculture, Western Waxed Paper Division of the Crown Zellerbach Corporation, Westinghouse Electric Corporation, Westvaco Mineral Products Division of Food Machinery and Chemical Corporation.

RECOMMENDATION

Students must be gotten into the mathematics habit early in their school experience. This involves not only straight mathematical ability but the additional habits of looking at problems with critical eyes, employing good judgment, and coming to constructive conclusions backed up with meaningful solutions.

FIFTEEN

FELLOWSHIPS—continued from page 28

of the following fields: biology, chemistry, mathematics, and physics; applied science seminars with field trips and plant and laboratory visitation. Six graduate credits may be earned. Twelve $250 fellowships and tuition provided by the du Pont Company to teachers of science and mathematics. *Dean of the School of Education, University of Delaware, Newark, Del.*

University of Minnesota. June 18-July 21. Institutes in the Physical Sciences (Chemistry and Physics) and Mathematics. Designed explicitly for the needs of high school teachers in these areas and operated simultaneously. Seventy $275 scholarships from the Louis W. and Maud Hill Family Foundation. *J. W. Buchta, Department of Physics or Bernard R. Gelbaum, Department of Mathematics, University of Minnesota, Minneapolis, Minn.* March 1.

University of Rochester. Six-Weeks Institute for High School Teachers of Physics. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *Howard R. Anderson, Dean of University School, University of Rochester, Rochester, N. Y.*

University of Utah. Five-Weeks Institute for High School and College Teachers of Biology. Fifty $250 stipends provided by the National Science Foundation; $65 for each dependent. *Loren C. Petry, Department of Botany, University of Missouri, Columbia, Mo.*

University of Wyoming. Five-Week Institute for High School and College Teachers of Physics. Fifty $250 stipends provided by the National Science Foundation; $65 for each dependent. *R. J. Bessey, Department of Physics, University of Wyoming, Laramie.*

Wesleyan University. Six-Weeks Institute for High School Teachers of Science. Fifty $300 stipends provided by the National Science Foundation; $75 for each dependent. *H. B. Goodrich, Department of Biology, Wesleyan University, Middletown, Conn.*

Wesleyan University. July 4-August 14. 1956 Graduate Summer School for Teachers. Scholarship recipients are expected to take two three-hour courses; courses may form part of the program leading to the degree of Master of Arts in Liberal Studies or, in the case of those who already have a Masters Degree, the Certificate of Advanced Study (sixth year). Twelve fellowships provided by the du Pont Company are available to high school teachers of mathematics, chemistry, and physics; size of grant will vary. *Joseph S. Daltry, Director of Teacher Services, Box 39, Wesleyan Station, Middletown, Conn.*

University of North Carolina. Twelve-Week Summer Session. A program for secondary school teachers of science and mathematics in the southeastern states; departments of chemistry, physics, botany, zoology, and mathematics have set up courses designed to supply the subject matter needs of graduate students. Awards are limited to qualified graduate students in the fields of education and appropriate content subjects; college staff members are not eligible. Sixteen $250-$350 fellowships and tuition provided by the

du Pont Company. *Director of the Summer Session, University of North Carolina, Chapel Hill, N. C.*

NOTE: The du Pont Company has awarded generous fellowships for the academic year 1956-57 in a number of the institutions in which they are offering summer fellowships. Those interested should contact the institution of their choice or write to Dr. Julian W. Hill, Committee on Fellowships and Grants, E. I. du Pont de Nemours & Company, Wilmington 98, Delaware.

SUMMER RESEARCH ASSISTANTSHIPS

Thirty-two or more universities will offer awards of about $400 for qualified science teachers to serve as research assistants with researchers in biological, physical, and earth sciences. For further information and application forms write to the Future Scientists of America Foundation of the National Science Teachers Association, 1201 Sixteenth Street, N. W., Washington 6, D. C.

TRAVELING SCIENCE TEACHERS

The Oak Ridge Institute of Nuclear Studies announces a new program, supported by a grant from the National Science Foundation, of assistance to science teaching in secondary schools for the summer of 1956 and for the school year 1956-1957.

A group of selected high school teachers will undergo a training period of three months in Oak Ridge, including the Second Annual Oak Ridge Summer Institute—June 11th through July 6th. During the school year, the teachers will spend approximately a week at each of many high schools giving lecture-demonstrations in science and otherwise conferring with teachers and students. The traveling teachers will receive a salary and travel expenses; they will also be provided with specially-equipped automobiles.

The program is national in scope and is designed to stimulate interest and competence in science teaching, to improve science teaching techniques, and to provide secondary school students with a deeper appreciation of science and the encouragement to consider scientific careers.

For further information write to the program director, W. W. Grigorieff, Chairman of University Relations Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tenn.

PROGRAMS FOR ACADEMIC YEAR

Oklahoma Agricultural and Mechanical College. Science Teachers Supplementary Training Program sponsored by the National Science Foundation. Designed to improve the competence of high school science teachers and those who wish to qualify as science teachers. Program will feature basic and advanced courses and laboratories in biological science, physics, chemistry, and mathematics; teaching methods and the applications of science in engineering, industry, and research. Participants may qualify for an MS degree in Natural Science from the Graduate School. Open nation-wide to high school science teachers with three or more years experience and to others with special qualifications. Fifty $3000 stipends plus fees and liberal allowances for dependents and travel. *Professor James H. Zant, Department of Mathematics, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.* March 15.

University of Wisconsin. Science Teachers Supplementary Training Program sponsored by the National Science Foundation. Each teacher will pursue a program of study planned specifically designed to increase his effectiveness as a teacher; programs will include refresher courses in the fundamentals of biology, chemistry, mathematics, and physics; a seminar in the teaching of science and mathematics; selections from regularly offered graduate courses in science and mathematics, and a course devoted to the impact of science on society, *Contemporary Trends.* Credit earned may apply toward a Masters Degree in science education or in biology, chemistry, mathematics, or physics. Qualifications for applicants are: 3 years experience, present employment as a high school teacher of science or/and mathematics, a bachelor's degree, under 46 years of age, adequate scholastic ability, and satisfactory recommendations. Fifty $3000 stipends plus fees and allowances for dependents and travel. *Professor C. H. Sorum, Department of Chemistry, University of Wisconsin, Madison 6, Wis.* March 1.

Presenting

NOMINEES FOR OFFICERS AND DIRECTORS for 1956-57

The following biographical sketches about the nominees include in this order: name; present professional connection; degrees; experience; activities; publications; honors; hobby interests.

Ballots are being mailed to all NSTA members. They should be marked and returned to the committee chairman, Prof. Ned Bryan, Rutgers University, New Brunswick, N. J., not later than March 5.

See also "NSTA Activities," page 58 of this issue of *TST*.

President-Elect

FABIAN BACHRACH

GLENN O. BLOUGH. Associate Professor of Education, University of Maryland, College Park. AB, AM, University of Michigan; LDD, Central Michigan College of Education. Instructor, University of Chicago; specialist for elementary science, U. S. Office of Education. Director-at-large on NSTA Board of Directors; member of NSTA policies committee; chairman of NSTA elementary science committee and editor of *Elementary School Science Bulletin;* member of planning committee for 1956 National Convention of NSTA. Past-president of National Council for Elementary Science; adviser to Educational Policies Commission; member of Conservation Project Committee for the National Association of Biology Teachers, Commission on Human Relations of the Association for Supervision and Curriculum Development, Committee on Teacher Education of the Association of Childhood Education, Editorial Advisory Board of *World Book Encyclopedia,* Editorial Board of *My Weekly Reader;* Counselor Service for *The Instructor;* educational consultant for Coronet and Instructional Films. Author and co-author of 26 books including *Elementary School Science and How to Teach It* and *Making and Using Classroom Science Materials;* numerous articles in a number of journals. Four books selected by Junior Literary Guild; Phi Delta Kappa; Phi Sigma; honorary doctor of laws for outstanding work in education.

DEAN C. STROUD. Science teacher, Amos Hiatt Junior High School, Des Moines, Iowa. AB, Des Moines University; MA, University of Iowa. Past member of NSTA Board of Directors as vice-president of north central region; co-director (state) for Iowa; member of evaluation committee for Packet Service. Executive Secretary for the Iowa Junior Academy of Science; 1955-56 delgate to Iowa State Education Association; past president of Des Moines Classroom Teachers and Des Moines Science Teachers; past secretary of Iowa Association of Science Teachers; member of committee for the general science course of study for the state of Iowa; course of study committee for general science for Des Moines Public Schools. Twenty-five year award of Des Moines Y's Mens Club of local YMCA for Hi-Y club activities; life member of NSTA and the National Education Association. Photography-movies and stills.

Secretary

GERTRUDE W. CAVINS. Head of Science Education Department, Professor of Chemistry, and Assistant Dean of Instruction, San Jose State College, Calif. AB, San Jose State College; MA, EdD, Stanford University. Alternate director for Region VIII on NSTA Board of Directors; chairman of NSTA affiliated group committee; co-director for 1955 West Coast Science Teachers' Summer Conference. Secretary of Pacific Southwest Association of Chemistry Teachers; secretary of Elementary School Science Association (Northern) California; registrar and secretary of West Coast Nature School.

CLIFFORD R. NELSON. Junior high school science consultant, Weeks Junior High School, Centre Newton, Mass.; formerly science teacher and chairman of science department. Wentworth Institute; BS (Education) and MEd, Boston University. Contributor to *The Science Teacher;* program participant at NSTA National Conventions. Charter president of the Science Teachers of New England. House designing and building.

Treasurer

LEE-EVANSON STUDIO

J. DONALD HENDERSON. Associate Professor of Physics, University of North Dakota, Grand Forks. BS (Education) and MS, University of North Dakota. Principal and teacher, Edina School, Minneapolis, Minn.; physics teacher, Minot State Teachers College; physics and chemistry teacher Crosby-Ironton Junior College. Director for Region VI on NSTA Board of Directors; chairman of NSTA policies committee for current year; NSTA state director for North Dakota; member of NSTA physical science committee; regional chairman for 1954 and 1955 programs of Science Achievement Awards for Students. Secretary-treasurer of North Dakota Academy of Science and secretary of the Academy Publication Committee; president, vice-president, and treasurer of North Dakota Chapter of American Association of University Professors. Joint author of a *Course Outline for Physics in North Dakota High Schools, General Physics Laboratory Manual* (Burgess Publishing Company), *The Evaluation of Faculty Services:* AAUP Bulletin, Vol. 34, No. 3, Autumn, 1948. Sigma Xi; American Men of Science. Woodworking.

BEN SWAN

RICHARD H. LAPE. Teacher of biology and head of science department, Amherst Central High School, Snyder, N. Y. BSEd, Buffalo State Teachers College; EdM, University of Buffalo. U. S. Air Force instructor in meteorology; instructor and lecturer in education, University of Buffalo; visiting consultant in education, Syracuse University. Current treasurer on NSTA Board of Directors and past eastern vice-president; chairman of several NSTA committees; member of Advisory Council on Industry-Science Teaching Relations; member of Magazine Advisory Board for *The Science Teacher;* regional chairman for program of Science Achievement Awards for Students. Member of New York State Regents Examination Committee in biology; president of New York State Science Teachers Association. Numerous articles in various science teaching journals. Phi Delta Kappa; New York State Science Teachers Association Fellowship Award; *Who's Who in American Education.* Photography; fishing.

Director, Region II

DOROTHY E. ALFKE. Assistant Professor of Science Education, Pennsylvania State University, State College. BS, MS, PhD, Cornell University. Math and science teacher, Bridgehampton and Guilford, N. Y.; instructor in science education, Oneonta State Teachers College. NSTA elementary science committee. Director, Pennsylvania State Science Teachers Association; elementary science editor for *PSSTA BULLETIN.* Articles published in *The Science Teacher, AIBS Bulletin, Elementary School Science Bulletin,* and *The American Biology Teacher.*

WILLIAM F. GOINS, JR. Assistant Professor of Education, Brooklyn College, N. Y. BS, Hampton Institute; MA, PhD, Ohio State University. Assistant professor of chemistry, Hampton Institute, Va.; professor of and chairman of department of science education, Tennessee State University, Nashville. Past member of NSTA Board of Directors as director-at-large; regional chairman for 1953 program of Science Achievement Awards for Students; member of planning committee for 1955 National Convention of NSTA; member of NSTA school facilities and policies committees. Fellow of AAAS; member of college level research committee of NARST; secretary-treasurer, Hampton Institute Chapter of AAUP; member of Science Talent Search Committee of Virginia; consultant to science and math section of Tennessee Education Congress. Collaborator on *School Facilities for Science Instruction* (NSTA) and *Critical Years Ahead in Science Teaching* (Conference on Nationwide Problems of Science Teaching in Secondary Schools). Beta Kappa Chi; Phi Delta Kappa; General Education Board Fellow.

HERBERT H. REICHARD. Physics teacher, Allentown High School, Pa. BS, MS (physics), Pennsylvania State University; MA (physics), University of Michigan. Mathematics teacher, Allentown High School; physics and math instructor, Pennsylvania State University Under-graduate Center, Hazleton; chairman, mathematics department, Beall High School, Frostburg, Md.; research assistant in electrical engineering, Harvard Engineering School. NSTA state director for Pennsylvania; member of 1955 nominating committee; member of extra-curricular activities committee; consultant at conventions and conferences for science teachers. President, Pennsylvania Science Teachers Association; founder and past president of Lehigh Valley Science Fair; vice-president of Physics Club of Lehigh Valley; life member of NEA, PSEA, NSTA. Articles in *The Science Teacher* and *AIEE Journal.* Phi Kappa Phi, Sigma Xi, Sigma Pi Sigma, Pi Mu Epsilon; award in 1953 program of Recognition Awards for Science Teachers; teacher merit recognition by Lehigh Chapter of ACS (1955). Photography.

LEE R. YOTHERS. Head of science department, Rahway High School, N. J. BS, University of Pittsburgh; MA, Columbia University. Evening faculty (zoology), Union Junior College, Cranford, N. J. Past NSTA state director for New Jersey; NSTA representative at National Association of Manufacturers conference in New York City. Guest editor and past associate editor of *The American Biology Teacher;* state director for NABT; New Jersey Science Teachers Association as president, vice-president, biology section chairman, member of executive committee, and editor of *NJSTA Bulletin;* member of eight scientific or science teaching societies. Numerous articles in science education journals and articles in newspapers reporting school-community activities; co-author of science section of the *New Jersey Secondary School Teachers Association Yearbook, 1950. Who's Who in American Education, (1950).* Rock and mineral collecting; fossil hunting.

Director, Region IV

KATHERINE M. HERTZKA. Chairman of science department and biology teacher, Hoke Smith High School, Atlanta, Ga. AB, Agnes Scott College; MS (biology), Emory University. Member of FSAF administrative committee, NSTA committees on health and biology; program chairman for 1955 winter regional meeting in Atlanta; regional chairman for 1956 program of Science Achievement Awards for Students. Chairman, biology curriculum committee for Atlanta schools; co-author of a teaching unit on tuberculosis for Atlanta Tuberculosis Association; scholarship for summer study at Harvard University (1952). "The First Week of School in Biology," *The Science Teacher*, April, 1954. Phi Beta Kappa; Phi Sigma; Delta Kappa Gamma; Kappa Delta Epsilon. Reading; cooking; bridge.

JOHN A. MANNING. Supervising teacher, Natchitoches High School, La. BA, Louisiana State Normal College; MA, Louisiana State University. Thirty years of teaching in field of science in Louisiana high schools; instructor in physics and theory of flight, Cornell (Iowa) Navy Flight Training Program; head, teacher training department, Escola Tecnica de Aviacao of the Brazilian Air Force, Brazil. NSTA state director for Louisiana. Member, science fair committee of Louisiana Academy of Sciences (1955); director, Northwestern Regional Science Fair. Various articles in *Louisiana Schools*. Westinghouse fellow, Carnegie Institute of Technology. Music; painting.

BIRDIE MCALLISTER. Supervisor of Science, Dade County, Fla. AB, University of Georgia; MA, Duke University. Head of science department, Miami Beach High School. Past-president, Dade County Classroom Teachers Association; life member of NEA; member of Board of Directors of FEA; state vice-president of Delta Kappa Gamma. *Flora of Key Biscayne* (article). Delta Kappa Gamma. Gardening; traveling.

ERNEST E. SNYDER. Associate Professor of Science, State Teachers College, Florence, Ala. AB, MA, Colorado State College of Education. Teaching fellow, School of Education, New York University. NSTA state and area director for Alabama; member of NSTA film excerpt committee. Chairman and vice-chairman, Science Education Section, Alabama Academy of Science; vice-president elect, Alabama Academy of Science (1956-57); NARST committee for the annual review of research in science education. Published articles in *Science Education, The American Biology Teacher*, and *Journal of the Alabama Academy of Science*. Building a house; farming; fishing; photography.

Director, Region VI

CUTLER'S STUDIOS

BROTHER I. LEO, F.S.C. Professor of Chemistry, St. Mary's College, Winona, Minn. BS, MA, De Paul University; PhD, Catholic University of America. Professor of Chemistry, Christian Brothers College; registrar, St. Mary's College; secondary school teacher for 10 years. Member of planning committee for 1955 National Convention of NSTA. Memphis Section Chairman, American Chemical Society. Articles in *Journal of Chemical Education, The Science Counselor, School Science and Mathematics, Catholic Educational Review*. Rock and mineral collector; interested in touring chemical plants.

NELLIE G. FLETCHER. Science and math teacher, Greybull High School, Wyo. AB, Nebraska Wesleyan University; MS, Kansas State College of Agriculture and Mechanical Arts. Science teacher, Park City High School, Utah; science and math teacher, Breckenridge High School, Colo.; chemistry instructor, Nebraska Wesleyan University. NSTA state and area director for Wyoming Senior class sponsor and *Annual* sponsor, Greybull High School; fellow at NSF conference for math teachers, Seattle, Washington, August, 1954. Phi Kappa Phi; Delta Kappa Gamma. Football fan.

HENRY E. GOBEL. Science teacher, Irving Junior High School, Lincoln, Nebr. BS, MA, University of Nebraska. Science and Math teacher, Friend, High School, Nebr., Program participant, NSTA fall regional conference, Boulder, Colo., October, 1953, and 1955 National Convention. Past chairman, Nebraska Junior Academy of Science and Science Section, Nebraska State Teachers Association; participated in science teacher workshops, Claremont College, Calif., and Harvard University. Chairman for one revision of the *Lincoln Curriculum Guide for Junior High School*. Stamps.

GERTRUDE M. OLSON. Biology instructor, Great Falls High School, Mont. BS, MS, Montana State College, State membership chairman for National Association of Biology Teachers; secretary, Science Section, Montana Education Association (North Central District); sponsor of high school FTA club. Delta Kappa Gamma.

Director, Region VIII

CARMELITA BARQUIST. Biology teacher, South Salem High School, Ore. BA, MA Willamette University. Member of evaluation committee for Packet Service; honorable mention entry in 1954 program of Recognition Awards for Science Teachers. Founder of Delta Kappa Gamma for state of Oregon; executive board member of AFT (Salem Branch). "The Uses of the Teaching Unit in Conservation," *Handbook for Teaching of Conservation and Resource-Use*, National Association of Biology Teachers. Painting; sculpturing; woodcarving; color photography.

JOEY STARR

EDWARD M. GURR. Chemistry and physics teacher, South Mountain High School, Phoenix, Ariz. BA (Chemistry), University of Illinois; MS (Education), Western Illinois State College. Industrial chemist with du Pont for 10 years prior to teaching. NSTA state director for Arizona; member of NSTA policies committee; NSTA representative to International Solar Energy Symposium, Phoenix. President, Arizona Science Teachers Association and Phoenix Elementary Classroom Teachers Association; official delegate to NEA national conventions 1953-1955; member of AEA convention committee, 1954-55. Phi Delta Kappa. Photography; science fairs; chess; travel; ceramics.

ROBERT A. RICE. Chairman, science department, Berkeley High School, Calif. BA, MA, University of California. Director for Region VIII on NSTA Board of Directors; NSTA state director for California, 1948 to date. President, vice-president, and treasurer of California Science Teachers Association (Northern Section); executive director, San Francisco Bay Area Science Fair, 1955 and 1956; meteorology instructor and civilian personnel officer, Army Air Corps. Phi Delta Kappa. Music; sports.

SISTER MARY CHARLOTTE (RAMSAY), C.S.C. Science teacher, St. Teresa's Academy, Boise, Idaho. BA, MA, Notre Dame University. NSTA state director for Idaho since 1952; program participant in Second National Convention of NSTA. Director of the Amateur Radio and Photography Club; has held amateur radio license for seven years for her school; Westinghouse Fellow at MIT, 1954. Articles published in *Catholic School Journal*.

The National Science Teachers Association

ANNOUNCES a new program of

SCIENCE TEACHER ACHIEVEMENT RECOGNITION

THIS PROGRAM of Science Teacher Achievement Recognition is designed to stimulate and recognize superior science instruction in grades 7 through 12 in public, private, and parochial schools of the United States. STAR is planned to encourage the development of creative ideas, teaching materials, and teaching techniques, and to secure the widest possible dissemination of such, for the purposes of:

A. Raising the general level of science instruction.
B. Influencing more young people to enter the fields of science and science teaching.
C. Helping young people to understand that the key to our science problems is more and better basic research.
D. Developing understanding that many fundamental science problems (such as the control of cancer) require the cooperative attack of specialists in fields as diverse as physics, botany, chemistry, physiology, mathematics, genetics, and bacteriology.
E. Developing a thorough understanding of the basic principles of biological and physical science and their application to such fields as health through presently established courses.
F. Developing more reflective and critical habits of thought.
G. Helping young people gain skill in scientific problem solving.

STAR is supported by a grant from the U. S. National Cancer Institute to the National Science Teachers Association. The National Cancer Institute made this grant because it appreciates the importance of the science teacher in developing a pool of young scientists from which may be recruited future leaders in research, science teaching, and other scientific professions.

It is emphasized that participants in STAR are restricted in no way as to content areas. Cancer information and materials are available, however, as a medium to serve and enhance the larger aims and purposes of STAR for teachers who may wish to use such as their vehicle for achieving the purposes of this program.

An announcement-application brochure about STAR will soon be mailed to all NSTA members and other science teachers throughout the nation. This will give information and procedures for those who wish to participate in the program. How to prepare submissions and the criteria for later judging of entries will be outlined in the brochure.

All entrants in STAR will receive appropriate certificates of participation. Approximately fifty submissions will be selected for special recognition, consisting of bronze medallions for the teachers and specially designed plaques for their schools. Ten of these submissions will be identified to receive STAR awards of either $200 in cash or three-day, all-expense trips to Washington for visitation to various scientific research centers in the nation's capital. Selected submissions will later be published in a booklet which will be widely distributed among all science teachers in junior and senior high schools.

Closing date for the 1956 STAR program is December 21, 1956. Presentation of awards will be a feature of the 5th National Convention of NSTA, to be held in Cleveland, Ohio, March 20-23, 1957.

Shown here are members of the STAR National Awards Committee. Reading from left to right are: standing, Dr. William F. Goins, Jr., Brooklyn College, New York City; Dr. Israel Light (*advisory member*), National Cancer Institute, Bethesda, Md.; Mr. Kenneth E. Vordenberg, Public Schools, Cincinnati, Ohio; Mr. James F. Kieley (*advisory member*), National Cancer Institute, Bethesda, Md.; Dr. R. Will Burnett, University of Illinois, Urbana; Dr. Ellsworth S. Obourn, U. S. Office of Education, Washington, D. C.; Dr. Murl C. Shawver, Madison College, Harrisonburg, Va.; Dr. Murray Copeland, Georgetown University Medical School, Washington, D. C.; seated, Mr. Robert H. Carleton, *Project director*, National Science Teachers Association, Washington, D. C.; Dr. John R. Heller (*advisory member*), *Director*, National Cancer Institute, Bethesda, Md.; Dr. Betty Lockwood Wheeler, University of Michigan, Extension Division, Mt. Pleasant, Mich.; Dr. Abraham Raskin, *Project secretary-editor*, Hunter College, New York City; Dr. W. Edward Chamberlin, School of Medicine, Temple University, Philadelphia, Pa. Also a member of the committee, Dr. Charles Cameron, Medical and Scientific Director, American Cancer Society, New York City, was absent when this picture was taken.

CHASE LTD., PHOTO

NSTA Activities

Report from Atlanta

The 7th Joint Conference of the AAAS Science Teaching Societies was a grand success. Nearly 500 science teachers registered for sessions of the American Nature Study Society, the National Association of Biology Teachers, the National Association for Research in Science Teaching, and the National Science Teachers Association. General sessions dealt with the growth of agriculture in the south, the frontiers of atomic science research, and the relations of science and human resources. Individual sessions of the societies provided new ideas and the exchange of experience with instructional matters as elementary science curriculum, the use of films, demonstrations, and tests in teaching, and the use of field trips. Social activity highlights included "A Christmas Interlude" provided by the Atlanta Science Teachers Club and the annual ANSS Presidential Dinner. Mrs. M. Gordon Brown was general coordinator of program and arrangements for the meeting. The meeting concluded with well-attended field trips to Stone Mountain and to the Communicable Disease Center of the Public Health Center. Plans were launched for the 8th Joint Meeting of the Science Teaching Societies to be held in New York City, December 27-30, 1956.

Executive Committee Actions

Th NSTA Executive Committee held two sessions during the Atlanta meeting. Important actions taken were as follows:

1. To support the resolution presented to the AAAS Council relative to future AAAS meetings:

> The American Association for the Advancement of Science is a democratic association of all its members; no one is barred from election because of race or creed. All members are privileged to cooperate freely in the fulfillment of the Association's high objectives which are the furtherance of science and human welfare. No member is limited in the service because of race cr creed.
>
> In order that the Association may attain its objectives, it is necessary and desirable that all members may freely meet for scientific discussions, the exchange of ideas, and the diffusion of established knowledge. This they must be able to do in formal meetings and in informal social gatherings. These objectives cannot be fulfilled if free association of the members is hindered by unnatural barriers.
>
> Therefore be it resolved that the annual meeting of the American Association for the Advancement of Science be held under conditions which make possible the satisfaction of those ideals and requirements.

2. To seek support of the National School Boards Association, American Association of School Administrators, and National Association of Secondary School Principals in developing a joint committee with NSTA to study and recommend on the employment of laboratory assistants in high school science laboratories.

3. To participate in the NEA plan of group life insurance for NSTA staff employees who desire it.

4. To strengthen and expand NSTA cooperation with the Oak Ridge Institute for Nuclear Studies in their program of conferences and other activities in the southeastern states; designated Dr. Herbert A. Smith of the University of Kansas (Board of Directors, Region VII) as official NSTA representative to a January meeting to begin planning for a Louisiana conference to be held next October.

5. Authorized continued planning with Washington State College pointing toward a science teachers conference there in the early summer of 1957.

6. Confirmed NSTA participation with the Arizona Science Teachers Association in a science teachers conference in Phoenix in the fall of 1956.

7. Selected Atlantic City, New Jersey, as location of the Seventh National Convention of NSTA, April 1-4, 1959.

8. Authorized and directed Executive Secretary to carry through on proposals for cooperative projects involving the Grolier Society, Models of Industry, Inc., the National Science Foundation, and the American Association for the Advancement of Science.

MAB Election

The Magazine Advisory Board for *The Science Teacher* is comprised of six members. Two members are chosen for three-year terms each year by the NSTA Board of Directors. Announcement was made at the Atlanta meeting of the two new members elected to serve during 1956-57-58. They are Dr. Paul Brandwein of New York City and Dr. Richard Armacost of Purdue University.

Dr. Brandwein is known for his teaching, writing, and lecturing; he is biology teacher and head of the science department of Forest Hills, New York, High School and a member of the staff of Teachers College, Columbia University; currently on leave to the Joint Council on Economic Education, he is serving as director of a special project in conservation education.

Dr. Armacost is joint professor of biology and edu-

cation at Purdue; is co-editor of *The American Biology Teacher,* the Journal of NABT; he serves part-time as science supervisor in the schools of Indiana and is well known for his popular radio program, "Meet the Biologist."

Retiring from the MAB after three years of service are Mrs. Archie MacLean Owen of the Los Angeles City Public Schools and Mr. Louis Panush of Northeastern High School, Detroit, Michigan. Mr. Panush is editor and publisher of *The Metropolitan Detroit Science Review.*

Continuing on the MAB are Dr. Paul Blackwood of the U. S. Office of Education, Washington, D. C.; Dr. Fletcher Watson of the Harvard Graduate School of Education, Cambridge, Massachusetts; Mrs. Edna B. Boon of Austin High School, Austin, Texas; and Mr. Richard H. Lape of Amherst Central High School, Snyder, New York. Mrs. Boon has been named to serve as chairman of MAB during 1956. NSTA members are invited to communicate with her on any criticisms, comments, or suggestions they may have to offer.

Report of Nominating Committee

Members of the Nominating Committee met at NSTA headquarters on December 9 and 10 to select a slate of candidates for office for 1956-57. A wealth of capable and dedicated persons had been suggested by members and officers of the Association and its affiliated groups. Geographical distribution, grade level, major science interests, and service to NSTA were among the criteria used in preparing the slate. See pages 47-53 for photographs of and biographical information about the nominees. The nominees are to be commended for their willingness to serve and all members are urged to vote in the election. Ballots now being mailed to NSTA members should be returned not later than March 5 to Professor Ned Bryan, Rutgers University, New Brunswick, N. J.

Members of the committee are Ned Bryan, *Chairman,* New Brunswick, N. J.; John B. Chase, Jr., Charlottesville, Va.; Gertrude D. Howard, Washington, D. C., Elra Palmer, Baltimore, Md.; Madeline Skirven, Baltimore, Md.; and Marsh White, University Park, Pa.

The 1956 annual meeting of the American Association of School Administrators will be held in Atlantic City, February 18-23. NSTA is cooperating in a joint meeting with AASA on Wednesday, February 22; the subject is a discussion group on "Science for Atomic Age Schools." Chairman of the group is Mr. M. L. Carper, Superintendent of Schools, Martinsville, Virginia; details and participants are not available at this writing. NSTA's official delegate to the AASA meeting is President-elect John S. Richardson of Ohio State University. All science teachers who are interested are cordially invited and urged to attend.

4TH NATIONAL CONVENTION OF NSTA

In planning our Association's 1956 Convention, the Program Committee has attempted to provide continuity of attention to a vital professional problem. We have based the program on certain "tenets of faith" from which emerged our theme—*Problem Solving: How We Learn*. It seems to us that:

1. Problem solving is characteristic of all life, to more or less degrees. Man stands unique among existing forms of life in the ability to introduce novelty into his problem-solving activities. The best example of the large-scale exploitation of novelty in problem solving is to be found in modern science.

Modern science has added a new dimension to man's problem-solving activities—namely, the scientific approach to problems, or, in the words of Dewey, "the method of intelligence rigorously applied."

2. Problem solving and learning go hand in hand. Some educators say that problem solving and learning are synonymous. In solving problems, we learn an array of skills, facts, principles; develop insight; enhance intelligence. "Learning" isolated facts, for example, is a consequence of trying to deal with factual information outside a problem situation. The well known "forgetting curve" simply documents this contention. In brief, no genuine problem situation *recognized as such by the learner*, then no interest, no motivation, no learning.

3. "Finding out" is the essence of problem solving and of the learning problem, but *how* we find out and *for what purpose* determine the genuineness and effectiveness of the learning. In finding out what is needed to solve a problem we may need to experiment, or to draw upon existing established knowledge, or to set up and carry on new investigations guided by established procedures. What needs to be found out or learned depends on the nature of the problem and on perception of the problem situation.

4. If the above tenets be true, or at least be acceptable as an operational base, then the educator is faced with a host of professional problems. How to identify problems of educational significance which are closely identified with a given field of human activity; how to help young people take a personal interest in such problems; and how to reorganize the science curriculum, indeed the school curriculum, in terms of problem situations so that students may progress from one problem situation to another rather than merely from chapter to chapter or textbook to textbook.

ON WEDNESDAY EVENING, MARCH 14, you will hear the keynote address, "The Learning Problem," to be delivered by Herold C. Hunt, Under-Secretary, U. S. Department of Health, Education, and Welfare. There will, of course, be other convention activities Wednesday afternoon, with registration opening at 1:00 p.m.

ON THURSDAY, MARCH 15, the theme for the day is *Learning How to Find Out*. It is often taken for granted in teaching that students in the course of time will learn what we wish them to learn by reading text materials, watching demonstrations, listening to lectures, workirg in the laboratory, looking at motion pictures, or making observations on field trips. This assumption is open to question and needs extensive examination and study. To help with this task of the day, the following key speakers will "carry the ball" in sessions for elementary, junior and senior high, and college levels: Fletcher Watson, Harvard Graduate School of Education; Stephen M. Corey, Dean of Teachers College, Columbia University; Leo Klopfer, Harvard Graduate School of Education; William H. Jackson, Tennessee A. and I. University; Harry Passow, Horace Mann-Lincoln Institute School of Experimentation, Teachers College, Columbia University; Paul DeH. Hurd, Stanford University; and Ernest Bayles, University of Kansas.

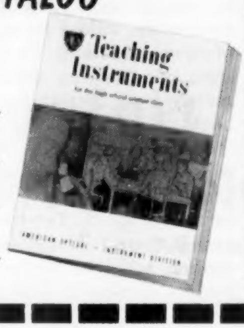
ON FRIDAY, MARCH 16, most of us will be visiting research centers in and near Washington in order to see how scientists go about *Finding Out What Nobody Knows*. We will be concerned to see "the pattern of scientific discovery" in action. Laboratories to be visited include: National Bureau of Standards, National Institutes of Health, Naval Ordnance Laboratory, Naval Research Laboratory, Agricultural Research Center, and U. S. National Museum. Speakers who will discuss "how scientists carry on research" in various fields of inquiry in afternoon sessions include: Dr. John Heller, Director, National Cancer Institute; Dr. George W. Irving, Jr., Agricultural Research Service, U. S. Department of Agriculture; Dr. Ralph E. Gibson, The Johns Hopkins Applied Physics Laboratory. The annual banquet Friday evening will feature an address on "Science in Human Affairs."

ON SATURDAY, MARCH 17, we will turn the spotlight on *Finding Out What We Have Learned*. Evaluation is an important phase of problem solving —and of learning. "Testing" is only one technique of assessing student growth and development. Good evaluation makes for desirable changes in pupil behavior, provides additional opportunities for learning and should assist in developing desirable skills, habits, attitudes, understandings, and appreciations. The keynote speaker will be Dr. Ralph W. Tyler, Director of the Ford Foundation for Advanced Study, Stanford University, California. As on other days of the convention, panels and discussion groups will "pick it up" and carry on. The convention wind-up will, as usual, consist of a series of "Here's How and Why I Do It" presentations.

Your committee has done its best to make this convention and your visit to Washington a fruitful and memorable one. No convention can be a success, however, without *your* presence and participation. Complete your plans now; make reservations early.

WASHINGTON, D. C.

MARCH 14–17, 1956



Teaching Instruments

FSA Activities

Summer Activities for Teachers

Applications are now being received from science teachers in the seven most western states for the third West Coast Science Teachers' Summer Conference. This will be another research-team type conference with the target being how to get the most out of time and effort invested in student projects. $200 fellowships are available for 32 people. The deadline is April 10, 1956.

As a service to those teachers who want to take part in special summer conferences, the names of all teachers who registered with the FSAF are being forwarded to the directors of such conferences. A similar service is being provided for teachers who are seeking science-related summer jobs in industry.

At the time this was written (January 10), 27 research laboratories had reported they will provide research assistantships for science teachers during the summer of 1956. The total group of participating institutions will be available on February 1. Additional teachers who are interested should contact the FSAF. A good story on this program appears in the January issue of the *NEA Journal.*

Tomorrow's Scientists

During each month of the present semester, every NSTA member will receive a copy of our new science student publication, *Tomorrow's Scientists.* Being the newest member of the Foundation's program family, we especially invite comments and criticisms. Each issue of Volume O is intended to provide specific ideas to be commended or abandoned. The content, style, format, in fact, everything about the whole idea is open for comment. Perhaps the four exploratory issues of Volume O will tell us whether or not students want another opportunity to read science stories written expressly for them and another way to keep in touch with each other.

Science Achievement Awards for Students

Remember—there have been several important changes in this program. The value of the awards has been greatly increased. Any type of project can now be entered in grades 11 and 12. There are national awards for projects at any grade level dealing with metals and metallurgy. *Most important of all, the deadline for entries has been moved up to March 15.* Be sure to send entries to Regional Chairmen.

FSA Science Chart-Making Contest

Important changes have also been made in this program. Charts must deal with how or why some scientific event has been accomplished. Prizes consist of $25 worth of science books of the winners' own choosing. Entries may come from individual students or they may be class projects. Closing date is March 1.

Booklet Services

New printings of *Careers in Science Teaching* and *Encouraging Future Scientists: Materials and Services Available in 1955-56* will allow the Foundation to continue making them available free on request. *If You Want To Do A Science Project* is in its third printing. Reports indicate it to be quite helpful. The price remains at 50¢ for individual copies or 25¢ each for two or more to the same address.

Financial Support of the FSAF

Although the Foundation receives contributions throughout the whole year, several new companies have already joined our Roster of Sponsors for 1956. As of January 10, the 1956 Roster includes:

American Can Company
American Society for Metals
Corn Industries Research Foundation
Crown Zellerbach Foundation
Dow Chemical Company
Fisher Scientific Company
The General Foods Fund, Incorporated
The Maytag Company Foundation, Incorporated
Rohm and Haas Company
Stauffer Chemical Company
Spencer Chemical Company
Weyerhaeuser Timber Foundation

BAYLES—continued from page 12

class that on which they are going to be examined. For this, teachers have only themselves to blame. They cannot with justification pass it off as evidence of moral degeneration on the part of students.

What did Persing find? That, although ability to recall was a very minor item among the objectives claimed by those teachers, recall items represented more than four-fifths of the examinations. And there is altogether too much evidence to the contrary to justify a rejoinder that those Cleveland schoolmasters were exceptional.

Moreover, it does not help a great deal to shift from memory items to generalizations or principles. This is indeed the transition which was sought by Professor Henry Clinton Morrison who was responsible for the Morrison plan to which I referred earlier. Of course, a science-teaching program becomes much more educative if it achieves understandings rather than mere fact-recall. But elementary and high-school education in the United States of America is presumed to be promotive of heightened competence on the part of students to become able and responsible members of a democratic society. It is presumed that, in this nation, public education should be focused upon achieving heightened competence to discharge one's responsibilities, as well as take advantage of one's opportunities, as citizens in a democracy.

If we consider democracy as a people governing itself, in which there is equality of opportunity to participate in making decisions coupled with equality of obligation to live up to the decisions once they have been made, it follows logically that public education must be primarily concerned with improving the capacities of its citizenry—present and prospective—to be wise in making decisions.

Even without instruction, a democratic citizenry is able to heighten its competence in decision-making. However, it is presumed that instruction can be designed so as further to heighten such competence. But, in order to do so, such a purpose has to be consciously recognized and careful thought has to be devoted to planning its achievement. Hence, democratic education would seem to have for its first and all-pervading purpose the promotion of self-dependence on the part of its members to arrive at wise decisions. This simply means that there is one competence which stands above all others as an objective of democratic education; that is the capacity to think for one's self. And the word "think" in this sense refers to the process of *arriving at* decisions rather than to the capacity to use or apply decisions or conclusions after they have already been made. The latter represents understanding-level thinking; the former represents reflection-level or scientific thinking.

Ability to carry out decisions, or to apply generalizations, is indeed an important objective of American public education. But in having this as an objective we are no different from the most fascistic or dictatorial of nations; for in an autocracy it is highly important that the citizenry be able to carry out the decisions or principles which have been adopted as governmental policy. Democratic education alone puts a premium on teaching people *how* to think—how to arrive at decisions. Autocracies join wholeheartedly in recognizing the necessity of helping people learn *what* to think.

There is a second great reason, moreover, why science teachers need to be majorly concerned with development of the capacity to think reflectively—to be independent learners. That inheres in the very nature of their own subject matter—science. What is the real genius of modern science? What is it that causes us to revere a person whom we deem worthy to be called a leading scientist? Is it what he knows—the scientific understandings which he possesses and is able to employ when need arises? Take Louis Pasteur as an example, one who surely deserves top rank among modern biological scientists. How much biology did Pasteur know? Before he started his investigations of silkworms, he is reported by DeKruif as not even knowing that silkworms go through a four-stage metamorphosis. And even at the close of his investigations he probably did not know as many principles of biological science as we expect of high-school biology students today. No, it was not the sum total of what Pasteur *knew* which made him great. It was, rather, his achievements in the process of *coming to know;* his achievements in scientific-reflective thought or investigation. It is because of its discoveries, and of its promise of further discovery, that we hold modern science in high esteem. We revere a scientific man, not for what he knows either as facts or as principles, but for what he can help us to learn. And it would seem high time that science education in the United States of America became aware of this fact and proceeded to do something about it.

Thus, if we view the genius of science not so much as organized knowledge although that is unquestionably an essential part of it but as primarily an organized and dependable way to *arrive at* organized knowledge, we see that the teaching of science must keep forever in the foreground the objective of learning how to get knowledge and of enhancing the capacity to be independent in so

doing. This means simply that science teaching, if it is to be true to the real spirit of science, should always be conducted so as to promote scientific-reflective investigations and, by way of classroom experiences of this kind, assist students in developing clear insight into the nature of scientific-reflective procedures together with keen realization of what such procedures will achieve and of their own capacities to carry them out.

And so we see that science teachers have a double obligation to teach reflectively: first and in common with all teachers in democratic schools, because democracy requires it; second and perhaps in addition to the obligations of teachers of other subject matters, because the fundamental spirit of science itself is embodied only in reflective teaching. And we must grant the full import of the fact (that is, the truth) that knowing is one thing and coming to know is quite another. We cannot be content with the false assurance that if we teach children *what* to think they will also learn *how* to think.

Children do indeed grow up, and they do so while in our classrooms. And growing up is perhaps more often than not accompanied by heightened capacity in how to think. However, if we are going to be worth our salt as teachers, we need to achieve considerably more than what will be achieved in the process of normal maturation. I fear that more frequently than not our teaching stands in the way of developing scientific-reflective capacity rather than promotes it. For when we put the premium which we do upon knowing as such, the members of our classes have to concentrate on what they must *know* rather than seek to improve their capacities in coming to know.

When my achievement on an examination is measured solely by the rightness of the answers which I give, my preparation must concentrate on knowing right answers—particularly what my examiner considers right answers. I cannot afford the luxury of thinking on my own because such thinking often leads me astray; particularly so when my teacher's answers are dictated by custom rather than by reflection. Should students not be helped, rather than hindered, by teachers? Should students not, to a degree at least, progress in educative directions *because of* their teachers rather than *in spite of* them? All this simply means that we, science teachers and teachers of science teachers, should practice reflective teaching rather than right-answer teaching.

I believe it unnecessary to dwell at length on the nature of reflective teaching. My experience has been that, once a person realizes that reflective and right-answer teaching are different from one another, he has little difficulty in comprehending the difference. It happened that way to me and I find it happens that way to those who study with me. For reflective teaching is merely a matter of handling classes so that members have opportunity to solve problems reflectively and scientifically. To accomplish such, a class must start with a question whose answer is at first to them unknown and, through study, arrive at an answer. The answer, conclusion, or solution comes at the end of the study and as an outcome of it. It is definitely and specifically *not* a case of asking a question, presenting *the* answer, then instituting training which promotes ability to use the answer. The latter may be called understanding-level teaching, but it is not reflective.

In reflective teaching, three processes assume importance and receive attention which they attain in only very small degree, if at all, when teaching is conducted on either memory or understanding level. These processes are (1) formulating hypotheses, (2) reasoning deductively, and (3) carrying on genuine experimentation.

There is too little realization by people at large of the true place and function of hypotheses in thinking. We talk much of scientific principles, but how many realize that no scientific principle ever becomes more than a hypothesis? Regardless of how confident we become of its validity, we can never say of a scientific principle or generalization that it represents ultimate and final truth—that beyond doubt we know it to be true. The very spirit of science is violated by assertions of indubitable knowledge. If the shift from Newton to Einstein means anything, it means just that. And if students are to be helped to *find* answers to questions rather than told the answers, it becomes necessary that they formulate and study likely possibilities; that is, hypotheses. In so doing, a number of valuable educational by-products ensue.

First, wrong answers as well as right ones are considered, leading to discovery of why the wrong ones are wrong as well as why the right ones are right. Second, in a search for hypotheses it is wise to find what others have done and, in consequence, reflective study naturally and almost necessarily requires investigation of the history of human thought on the problem. Thus, the history of science becomes woven into the warp and woof of an entire course and ceases to be something to which a single unit is to be exclusively devoted. Third, youngsters who study science in this manner have a whale of a good time at it. And, fourth, because

selection and rejection of hypotheses is genuinely sensed by students as their own responsibility, they become truly appreciative of the scientific attitude and are not likely to fall into the fallacy of considering that the expression, "Science says," gives to a proposition a degree of finality equal to, or even greater than, the expression, "God says."

Once hypotheses have been formulated, they must then be tested. And the first step in testing is the drawing-out of implications by asking, "If this be true, what then?" In other words, the logical consequences of each hypothesis are deduced. This is logical reasoning or deduction. To promote this coercive tightness of logical thought has been an educational objective for millennia, but an elusive one. It is an essential part of scientific investigation, and students who are taught reflectively are required to use it. In such a context or setting, the practice which is gained has likelihood of being highly effectual.

And after hypothesizing and deducing the implications of the hypotheses, genuine experimentation follows. If a given hypotheses be true and if certain things be done, then certain results will come. Setting up the conditions and carrying out the manipulations in order to see what will happen is experimentation. It is far more than merely observing what is to be observed; such, for example, as drawing the external aspects of a grasshopper then cutting him up and drawing his insides.

To keep within the space limit of a magazine article is difficult, and has been achievable only by hitting the high spots. I can only hope in some measure to indicate what I have found to be a blind spot in our teaching of science teachers and something of what might be done about it. Mr. Mills and I have written a high-school text, *Basic Chemistry*, in which we have tried, with perhaps some success, to conduct reflective studies of problems of a chemical nature and thus to be of some help to teachers who are trying to teach that way. I well remember, in a private conversation years ago, Otis Caldwell observing that teachers who are trying to inaugurate forward-looking ways of teaching deserve to be supplied with published materials which will help them. But salesmen for the Company have frequently run into the comment by prospective users, "Yes, it is a good, well-written book. But we just don't teach that way." Other authors of attempts at forward-looking ways of teaching report similar experiences. That is what distresses me with science teaching in this nation. It is not reflective teaching, yet it ought to be.

KEESLAR—continued from page 14

tell his neighbor, "All I have to do is just 'figger' long enough, and I can usually make these experiments turn out right!" He meant that he had only to introduce sufficient small errors *in the right direction* in reading his measuring instruments to do this, since he invariably knew the "right answer" before he began the experiment. He had no trouble getting that from the textbook. Of course, we know that his crime was actually closely akin to cheating at solitaire—and under the circumstances, I suspect it was just about as serious!

Besides establishing this peculiar kind of working relationship with the minds and personalities of our students, we can use certain devices to jockey our class into situations where scientific attitudes and methods of problem solving are naturally brought into play. The best device I know is not original with me, and I give credit for it to our good friend, Glenn Blough: [4]

"Proving" a Well-known Fact—First, I select some fact well-known to the class (such as a seventh grade I recently visited), and pose it as a question: "If wind blows on something that is wet, will that make it dry off any faster?"

"Yes!" (Of course, there is no doubt in their minds about this.) Then I say, "How would you *prove* it?"

There is usually a long moment of stunned silence, because science lessons are not customarily conducted in this way. Then a couple of boys jump excitedly to their feet, arms waving, "You'd have to show it happening!"

"How would you do that?"

They are still looking at each other and mulling it over, when a little girl holds up her hand a bit timidly, "Well—first I think you'd have to have *two* of them. One that has wind, and the other that doesn't," and thus we are off to one of the most spirited and intriguing science lessons I have ever tried to teach. (Incidentally, lest you doubt the veracity of my story, I learned later on inquiry that this little girl had seen the Coronet film, *What is Science?*, a couple of weeks earlier!)

Two boys and two girls are then invited to act as a team to *prove* that moving air speeds up the drying process. The rest of the class are judges of that proof. It is something like "Put up, or shut up!"—and if the class know their scientific methods at all, they are extremely critical and exacting. Two wet spots are rubbed on the chalkboard with moistened rags, and one of them is fanned with a sheet of pasteboard. If the spots are too close together, there is violent objection; if one is wetter than the other, there is objection; and so on, until the fact in question is "proven" to the satisfaction of everyone, including the teacher. What better way is there to get first-hand evidence of the scientific-mindedness of youngsters?

The Demonstration That Failed—I suppose there are teachers who lie awake nights in dread of the science "experiment" that may fail to work right. We all know such things do happen, in the best of families. The tin can does not collapse under air pressure; the hot plate doesn't get hot; the static machine won't deliver a charge; the model airplane keeps diving into the ground; or perhaps the model geyser will not erupt at all, or it erupts continuously. The guinea pigs on the diet of no-vitamins are healthier than their mates in the control pen (thanks, in one case I know, to foods innocently smuggled to them by the janitors!) And so on. The situations thus created are the most valuable you could hope for, to watch the scientific-mindedness of your students come into play. "What's the matter?" "Why doesn't this thing work?"

Historical Anecdotes—Additional help in the study of scientific methods may be drawn, as Dr. Conant suggests, from the lives of scientific-minded men and women of the past—scientists and laymen alike.

A splendid example of a great scientist's failure to follow through in scientific method is found in Charles Darwin's *Voyage of the Beagle* (volume 29, pp. 369-370, of the *Harvard Classics*). In July, 1835, Darwin visited the coast of Peru during an epidemic of ague or malaria, as we now know it, and was greatly concerned about the origins of a poisonous wind or miasma, which he believed caused the disease. He wrote a page and a half of observations supporting his belief, which show the amazing insight of the man, who was then only 26 years of age. Among them were:

a. Malaria was common on the coast but unknown in the high country inland.
b. It was most common in cities which had a few stagnant, though very small, pools of water somewhere near them.
c. The cities were made more healthful by draining these pools.
d. Malaria was worst during the weeks immediately after the rainy season.
e. One ran the greatest risk of catching malaria if he went ashore to sleep.

[4] Blough, Glenn O., and Blackwood, Paul E., *Teaching Elementary Science—Suggestions for Classroom Teachers.* Bulletin 1948-#4, Federal Security Agency, U. S. Office of Education, Washington, D. C., p. 24.

f. Those who slept on board a vessel, although it was anchored only a short distance from shore, suffered less than those who went ashore to sleep.

g. Marshes and dense plant growth alone did not seem to be the cause or source of the fever, for some parts of the jungles of Brazil were much more healthy than the sterile coast of Peru.

There were others, but *all* the observations Darwin noted are true and pertinent as we know now. He was on the trail of the real culprit, the mosquito, but he never caught up with it because he did nothing to check his hypothesis. Fifty or sixty years later, Ross (malaria) and Reed (yellow fever) proved how close he was to the answer.

In contrast, the public trial of Pasteur's anthrax vaccine in 1881 affords a perfect example of modern scientific method in action. The Teaching Film Custodians' *Story of Louis Pasteur—Anthrax Sequence,* with Paul Muni as Pasteur, is excellent study material for a class sufficiently advanced in maturity to speak and think in terms of experimental factors, controls, check experiments, and other elements of scientific methods. In the film the scientifically controlled test of the vaccine stands out in stark simplicity of design in spite of the uproarious controversies surrounding Pasteur's work at that time, and no student can help but feel that Pasteur's methods and motives, his attitude toward his bigoted opponents, were *right,* as well as honest and noble.

In closing, I want to say with all the conviction of my soul: You cannot leave this important aspect of science teaching to be handled in *incidental* fashion, while pursuing other goals. "Incidental teaching is *accidental* teaching!" You have to work at it, directly and deliberately, with all the skill and ingenuity you can muster. You have to come back to it, time after time. You have to plan it into your courses—keep it forever before your students—and know that there is nothing in the field of science more worthy of your attention.

RUTLEDGE—continued from page 26

Rahn, Herman R., "Purposeful and Meaningful Chemistry Laboratory Work," *School Science and Mathematics,* 47: 614-616, October, 1947.

The use of problems proposed by students for a portion of the chemistry laboratory work is described.

Richardson, John S., "Experimental Science—Brief History and Present Outlook," *The Science Teacher,* 17: 164-166, 197, November, 1950.

The need for real experimentation is voiced. Pertinent literature dealing with experimental approaches to science teaching is reviewed. Much of the material reviewed is concerned with problem-solving activities in science.

Richardson, John S., and G. P. Cahoon. *Methods and Materials for Teaching General and Physical Science.* New York: McGraw-Hill Book Company, 1951. Chapter 5.

The abilities and skills needed in problem solving or thinking are cited and Keeslar's list of elements of scientific method for high school students is presented. The use of demonstrations in teaching for thinking is discussed and examples of procedures are given. The use of the laboratory in teaching for thinking is discussed and emphasis is placed upon providing a variety of student problems.

Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I. Chicago: Distributed by University of Chicago Press, 1947. pp. 29, 32-33, 93-95, 144-147, 166-176, 197-198, 203-207.

Problem solving skills are discussed and illustrated. Basic elements in the process of problem solving are described. Suggested procedures for the development of skills in the use of these elements are presented.

Science in General Education, Report of the Committee on the Function of Science in General Education, Commission on Secondary School Curriculum, P.E.A. New York: D. Appleton-Century Company, 1938, pp. 306-324.

The values of problem-solving experiences in encouraging reflective thinking are pointed out. Reflective thinking is defined in terms of problem solving. Specific ways in which the science teacher may encourage reflective thinking through problem-solving activities are suggested.

Smith, Arthur W., Jr., "A Problem-Solving Demonstration," *The Science Teacher,* 22: 295-297, November, 1955.

An introduction to problem-solving techniques through a demonstration in ninth-grade general science is described. Apparatus and the procedure followed are given in some detail.

Stopak, Evelyn, "Pre-Kindergarten Children Learn About Machines," *The Science Teacher,* 20: 62-63, March, 1953.

Simple problem-solving experiences with very young children in work with machines is presented as a part of this article.

GREENLEE—continued from page 16

bring a general science book too. Can you remember the names of the books or shall I write them for you?" "Yes, write the names for me," replied Mildred.

Mrs. Monroe and the children found the information in all of the books, including the encyclopedia. They found that the speed of sound was about 1100 feet per second. Mrs. Monroe told the children that there were 5280 feet in a mile and that there were 52,800 feet in ten miles. She divided this distance by the speed of sound and got 48. She said that she didn't know if that was right or not but that they could ask Mr. Mitchell. Mr. Mitchell seemed a bit surprised with their question, but agreed that the result was correct.

During the next morning Mrs. Monroe and the children made plans to see if they could hear the distant whistle. By noon they had decided that it would be a good idea if they were out on the far end of the school yard, away from the noise of the building. Mr. Mitchell was with them. He had asked if he might come along to help. He brought a stopwatch. Mrs. Monroe's watch had a second hand on it and she had borrowed a pocket watch. She had checked the time and carefully set both of her watches. They were expecting to hear the distant whistle at 48 seconds after twelve.

Twelve o'clock came. The seconds seemed to pass slowly. Finally, Mr. Mitchell held up ten fingers. He lowered one each second. Three fingers were still erect when they heard the distant whistle. Mrs. Monroe said, "Forty-five seconds. We missed it by three seconds. Mr. Mitchell, I hope you can come into my room sometime this afternoon. I am sure I will need help." He replied, "I was going to ask if I might do so. I am beginning to see that I can learn some things about teaching science from you. I am ashamed to admit that I never thought of doing this sort of thing with my physics students."

The investigation continued over the next several days. The children learned that the air distance to the next town was a little short of ten miles and that wind direction and velocity, as well as the temperature, make a difference in the speed of sound.

A sixth-grade group was comparing the length of time that candles would continue burning under different-sized containers.

Simultaneously, they placed a glass tumbler, a quart jar, a gallon jar, and an aquarium, each over a separate lighted candle. One of the children said, "Well of course, we expected that," as the

candles stopped burning, beginning with the one under the smallest container. "Naturally all of the oxygen was used in the tumbler first because there was less there to start with."

The teacher explained, "As I understand it, the candle flame goes out before all of the oxygen has been used. In fact, the air is still about 15 to 16 per cent oxygen when the flame goes out." He explained further that the air was about 1/5 oxygen to start with and that after the flame went out it was about 1/6 oxygen. He explained that the fire actually utilized only the difference between 1/5 and 1/6 of the air or 1/30 of it. He told them that an animal such as a human being or a rat would die for lack of oxygen when the air around it was still about 1/6 oxygen.

Freddie said, "I want to see if I can prove that. Could I try an experiment with a rat and see? I don't know just how I would do it but I would like to try." One of the other children said, "You mean you are going to suffocate a rat?" Freddie answered, "Of course not. I will plan some way to get it out real quick just as soon as it stops breathing and then I will revive it by artificial respiration."

Freddie asked if the teacher had ever done anything like that and then said "But, I don't want you to tell me how to do it. I just want you to help me arrange times for doing it and help me get the things I will need to do it with." The teacher agreed and planned a time when he could meet with Freddie and the other children who wanted to help with the investigation.

First of all, Freddie had to plan a way of determining what portion of the air was oxygen to start with as well as after his rat had passed out. He also wanted to plan this independently of the teacher. He found a procedure for putting steel wool in a bottle filled with air, then inverting the bottle with the mouth under water. As the steel wool rusted, using oxygen in the process, air pushed water in, taking the place of oxygen. He tried the procedure and got the predicted results.

Freddie filled a bottle with oxygen, which the teacher had provided as a means of verifying his hypothesis that when steel wool was placed in a bottle filled with pure oxygen and arranged as above, water would completely fill the bottle.

His first idea was to get an aquarium and place a stone in it. Then he would pour water around the stone. Finally he would put his rat on the stone and invert a transparent dish over both rat and stone. He could then watch the rat and know when it stopped breathing. Freddie was sketching the arrangement of apparatus on the chalk board as he talked to his teacher about it. The teacher said, "But Freddie, that—." Freddie interrupted with, "Don't tell me how to do it. I want to plan it and if it doesn't work, I will try it another way." He completed the sketch, then said, "Wups, that won't work. I can tell when the rat stops breathing, but when I take him out, there goes my air."

The teacher had an idea, but Freddie said, "Please, just don't tell me. I can see that this won't work, but I will plan something that will." A few days later, he told his teacher that he had it planned so he thought it would work for sure if the teacher could get him the things he needed. Freddie asked for a piece of glass tubing, about two inches across, two one-hole stoppers to fit it, small lengths of glass tubing to fit the stoppers, a large cork stopper that would move freely inside the large glass tube, rubber tubing, two similar bottles, steel wool, a dish, and supports. He had decided to use a mouse instead of a rat.

Freddie arranged a support to hold the large glass tube upright. He put the short glass tubes into the stoppers and put the rubber hose onto each small glass tube. Then he put the mouse on the cork stopper and placed it in the cylinder and put a large stopper in either end of it. Finally, he attached the bottom rubber hose to the hydrant.

Freddie explained that as water flowed into the bottom of the cylinder, the cork would float, keeping the mouse dry, and the water would push the air out of the cylinder through the top rubber tube. He had two glass bottles, one of which was filled with ordinary air and inverted with its mouth under water. This bottle had steel wool in it and was to serve as a check or control. The other bottle was filled with water and inverted over a dish of water. Freddie had planned that as air was pushed from the end of the rubber tube and under this bottle, it would enter the bottle. The steel wool in this bottle would then be in air in which his mouse had passed out.

Freddie explained, "The rubber tube will have ordinary air in it after the mouse passes out. We will have to let some water in, pushing out enough of the air so the rubber tube will have air that the mouse passed out in." The teacher was ready to turn the water on when and as directed. Freddie watched the mouse and just as soon as it stopped breathing said, "Now turn it on slow." He waited until the cylinder was about half filled with water, then said, "Shut it off for a minute."

He pushed the end of the outlet tube under the mouth of the bottle, and the teacher turned the water back on. The bottle was soon filled with the

air that had been in with the mouse. Freddie took out the top stopper and took the mouse off of the cork when the water lifted it to the top. The mouse didn't even get its feet wet and was soon revived. Freddie's experiment had been his chief concern for about six weeks. It took very little of the teacher's time. Incidentally, his measurements revealed that the difference in the amount of air removed as oxygen from the control and the other was precisely 1/30. Freddie's measurement seemed sufficiently accurate for his purpose.

Classroom experiences, such as those just described,* are not rare; neither are they common enough. Surely, few people would question the effectiveness of the learning, the development of a scientific method, the growth in scientific attitudes of the children involved. These procedures are not suggested as a method for teaching *all* content in science. However, it is suggested that opportunities analogous to the above constitute a necessary part of the content of each science course. The way in which we teach is equally as important as what we teach.

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* These descriptions were taken from Greenlee, Julian, *Teaching Science To Children*, Revised. Dubuque, Iowa: Wm. C. Brown Company, 1955.

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